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EVOLUTION AND MAN

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FOREWORD

The story of the relationship of living plants and animals to one another and to their ancestors preserved as fossils in the strata of the earth has been told in many books. There seems, however, value in presenting the facts and theories of evolution as a basis on which to discuss man in particular, — his ancestry, his present inherited body and impulses, and how these condition his reactions to his environment.

The present volume emphasizes, moreover, the fact that evolution is not merely a matter of diverging physical forms but also of enlarging consciousness expressed through these evolving forms,— a consciousness that, when the human level is reached, takes an increasing control of both the physical and the social environment. In order that these hereditary forces may be used to larger social ends it would seem to have become increasingly true that "the proper study of mankind is man."

HERVEY W. SHIMER

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EVOLUTION AND MAN

I

INTRODUCTION

All are but parts of one stupendous whole,
Whose body nature is, and God the soul.

POPE

CHAPTER I

EVOLUTION: THE RESULT OF CONSTANT CHANGE

Evolution is the changing of one form into a different form through a sequence of cause and effect.

In my garden is planted the Cortland apple, formed in the New York Agricultural Station at Geneva in 1898 by the hand fertilizing of stigmas of the Ben Davis with pollen from McIntosh blossoms. The result is a combination of the hardiness of the former and the flavor of the latter. Here, too, grow the Concord grape, developed by Ephraim Bull from the wild Fox grape, probably through natural crossing with the Catawba; the cabbage, Brussels sprouts, and cauliflower, all produced by selection from natural changes in the wild cabbage growing on the sea cliffs of the shores of Europe; and the maize, potato, and tomato, developed by the Mayas and Incas through selection from wild American stock.

What is true of these garden products is also true of nearly all other food plants cultivated by man. Man has either consciously united different forms or, more usually, has selected from natural changes the forms most suited to his needs. In all cases the result was a change into a different form under the action of a sequence of causes and effects. When Luther Burbank wished to produce a spineless cactus, he selected the least spiny plants of successive generations until he had a spineless one. The ancient Mayas of Central America, by a similar process of selection, produced the large edible tubers of the potato, the enlarged roots of the cassava, the large grains and ears of maize.

What is true of plants is true likewise of animals. From the time of the earliest records to the present time man has gradually been changing his domestic animals into forms

better suited to his desires. The American-bred Boston terrier is the result of a cross between the English bulldog and the English terrier and the elimination, later, from the litters of the interbred descendants, of those individuals possessing pronounced characteristics of either ancestor.

The same kind of changes that man produces through his selection of minute variations takes place in nature, though much more slowly, for man keeps the plants or animals which show the slight changes in the direction of his desires from crossing with the unchanged forms or with those changing in undesired directions. All through plant and animal life we see the natural changes in form, such as man has taken advantage of in his selections. The shape of the scallop shell of the Atlantic shores of North America and Europe is gradually changing. It differs from that of the scallops eaten by the Indians of early New England, as is shown by remains found in the kitchen middens of the close of the Glacial Period.

When fossil shells and the fossils of other animals and plants that were living at still more remote times are examined, they are found to differ still more widely from the corresponding animals and plants of today. The farther back we go in time, the greater the change in all organic remains. The camels and horses of the Pleistocene differ slightly from those of today; those from the Pliocene differ more; those from the Miocene, still more. Studying the fossils from the Cenozoic rocks of North America, we see that the horse and camel changed slowly during the passage of time. Beginning in the Eocene as forms about the size of a small dog, they gradually increased in size while the number of toes decreased (from four to one in the horse, from five to two in the camel) down to the Pleistocene. From its first occurrence in North Africa in the Eocene the elephant similarly increased in size to the Pleistocene, and developed tusks from his upper incisor teeth and a trunk from a short, tapir-like snout.

All man's inventions are examples of evolution, for each new device arises through small additions to and changes

from an older form. The cause, the mind of man, stimulated by the need of the moment, acts on already existing forms and gives rise to the effect, the invention of new forms.

Language is subject to similar evolutionary laws. Through modifications of existing words and forms of speech, as well as by the addition of new elements and the dropping of old ones, a language gradually assumes a new form. Through a sequence of cause and effect one language gradually changes into a different one. Modern English, German, and French are the resultant of many causes, — true products of evolution.

Change is everywhere, at times faster, at others slower. Never is there stability in either the inorganic or the organic realm. These changes, cyclic in the former, progressive in the latter, are brought about by causes which in their origin are either within or without the object acted upon. Many of these causes are well known, others are as yet but imperfectly comprehended, but always one form changes into another form through a sequence of cause and effect. Solid rocks at the surface of the earth change into loose sand and clay. Land areas are raised into mountains, which are in turn gashed by canyons. The canyons widen into broad valleys until the mountains have disappeared.

> "The hills are shadows and they flow
> From form to form and nothing stands."

The forms of plants and animals living today are changing at a slower or faster rate into different forms, and fossils show us that such change has been in progress since the inception of life upon earth a billion years ago. Man is subject to the same law. His skeleton, his implements and buildings, all that he does or thinks, his very language, demonstrate these evolutionary laws.

In all the observed universe it is true that

> "A subtle chain of countless rings
> The next unto the farthest brings."

II

FROM THE INORGANIC TO PLANTS AND ANIMALS

The one Spirit's plastic stress
Sweeps through the dull dense world, compelling there
All new successions to the forms they wear;
Torturing th' unwilling dross that checks its flight
To its own likeness, as each mass may bear;
And bursting in its beauty and its might
From trees and beasts and men into the Heaven's light.

SHELLEY

CHAPTER II

EVOLUTION OF THE ENVIRONMENT OF LIFE

Evolution may be defined, according to the derivation of the word, as an unfolding. The term as used today implies, further, that the resultant of forces within the body, be it plant, animal, or the earth itself, when acted upon by forces from without, develops new capacities and new forms out of the old. These effects are in turn causes, which continue to produce new effects as long as reaction continues between the internal and the external forces.

In other words, evolution is a change of one form into a different form through sequence of cause and effect, due to the interaction of internal and external forces. The definition applies to plants and animals as well as to the inorganic realm.

Evolution of the earth. A nebula, composed of matter rarer than the air we breathe, is acted upon by its own gravitational and other forces and becomes progressively smaller and hotter. The star into which it thus evolves changes in color from red, the present stage of Betelgeuse and of Antares, through yellow to white, the present stage of Spica. When the matter of which a star is composed becomes under contraction so dense that it can no longer behave as a perfect gas, its surface gradually cools and hence changes in color from white through yellow to red, and finally ceases to shine from its own light. Our sun is a yellow star of this later contracted stage. When to stellar evolution, progressing thus mainly through the agency of its own internal forces, is applied such outer impetus as the near passing of another star, a solar system may be initiated. It is supposed that our ancestral sun, during its earlier evolutionary history, thus came under the influence of some other stellar wanderer.

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Even yet our sun hurls explosive gaseous matter to great distances from its surface, and these explosions were undoubtedly of far greater extent in its early history. The approach of the larger star would draw such semiliquid matter to greater distances, and, imparting to it an orbital motion around the sun, would prevent its return thither. The gathering together of successive ejections of this material into separate balls under the influence of gravity would produce the planets (earth, Jupiter, etc.) and their satellites. These would gradually cool, and in the larger depressions upon the surface would accumulate the water (embryonic oceans) developed on the cooling of the planet's surface.

Incoming of air and water. The spectroscope demonstrates the presence of hydrogen, oxygen, carbon, nitrogen, and many other elements upon each star that is in the requisite stage of evolution to exhibit them. Since the affinity of hydrogen and carbon for oxygen increases as the temperature falls, it follows that every dark, that is, every cooled, celestial body large enough to possess sufficient gravitational attraction must bear, upon its surface, water and an atmosphere of which carbon dioxide is the most important constituent. That free oxygen was later added to the earth's atmosphere through the action of plants upon carbon dioxide is indicated by the following considerations: (1) oxygen has not been found in a free state in meteorites or crystalline rocks; (2) today the living green plant is the only agency which stores up the carbon from the carbon dioxide of the air, thus giving free oxygen to the air; (3) the oldest known sedimentary rocks of the earth, those of the Archeozoic, inclose enormous quantities of carbon; (4) the earliest known red sedimentary rocks, that is, those indicating by their red color that they were formed in the presence of much free oxygen in the air, are from the upper part of the next younger era, the Proterozoic. None are yet known from the Archeozoic.

External forces of the earth and their work. When a planet has developed so that it has water and air upon its surface,

with the sun pouring heat upon it, certain results must follow. Because of the curvature of the planet more heat is received at the equatorial zone than at the polar, and this unequal temperature gives rise to the primary winds. The sun's rays evaporate the water, which is then carried by the winds as water vapor into colder regions and must here condense and fall as rain.

This water, as it flows over the land, varies in composition because of substances which it has absorbed from air and earth; the resulting acid and alkaline waters thus become powerful disintegrating agencies. The rocks of the earth's surface are subjected to their action and to changes in temperature, and later to the erosive power of water, wind, or ice; the result is loose soil of varying chemical composition and porosity. Thus, through such a cycle, varying kinds of rock, acted upon by varying external forces, evolve into soil of definitely varying constituents.

TABLE I. EVOLUTION IN ROCKS

The arrows point to the effects produced by the given external forces upon the underscored substances. (Life activities are external forces from the standpoint of the evolution of rocks, but from the viewpoint of the evolution of plants and animals they are, of course, internal forces)

EXTERNAL FORCES		SUBSTANCES		
Acid waters etc.	acting on	Rocks of varying chemical composition ↓	↓	
Running water	acting on	Lime in solution ↓	Sand and mud (soil) ↓	↓
Life activities	acting on	Lime in streams and ocean ↓ Shells, corals, etc.	Valleys	Soil ↓ Plants

The rain falling upon the surface of the land very gradually wears it down, carrying the sand and mud and the dissolved lime to lower-lying lands or to the ocean. Water thus at work develops the various minor topographic features seen upon continents, such as soil, ravines, river valleys and

lowlands, caves, swamps, and lakes. At the same time the margin of the ocean, acting like a huge saw whose teeth are the waves, cuts away the land. The final result of the action of these external forces, the chief of which are, in the ultimate analysis, the heat of the sun and the gravitational pull of the earth, would be the removal of all the land, particle by particle, beneath the surface of the ocean.

Internal forces of the earth and their work. This ultimate goal of the external forces, however, has never been attained throughout the many millions of years of known earth history. Counteracting forces resident within the earth, of which internal heat and the gravitational pull toward the center of the earth are the most important, always push up more land in the form of mountains, plateaus, and coastal plains, and also pour out molten rocks.

The pressure and heat developed during the folding and upheaval of mountains, acting upon the rocks thus moved, produce marble, anthracite, graphite, magnetite iron, slate, etc., according to the original composition of the rock and the amount of heat which the folding develops.

Effect of geologic sequence upon man's activities. The presence of such economic products in turn helps to determine whether man shall occupy these regions. That is, the economic necessity of building a railroad into such a region is the result of a sequence of cause and effect reaching back millions of years. Such a sequence has, for example, determined the transportation of iron ore from Wisconsin, first by boat across the Great Lakes and then by rail to the coal-producing regions of Pennsylvania and Indiana. The iron was developed during the very early pre-Cambrian times of earth history, the coal much later during the upper Paleozoic, while the Great Lakes (with the exception of Lake Superior) evolved through river erosion during the Tertiary and through glacial damming during the later Pleistocene.

Summary. We see that the environment in the midst of which plants and animals are today living has had a slow

evolution.[1] Carbon dioxide, free oxygen, water, various combinations of carbon, hydrogen, and oxygen, the ocean and soils, highlands, lowlands, streams, and ground water — all of them factors in the variation of plants and animals — came slowly into existence through a sequence of cause and effect. To different phases of this environment we see that plants and animals are today molded so as to fit each particular niche, just as man becomes molded to his life's work. So perfectly are organisms adapted to their environment that there is hardly an element which is common to all life that could be changed without causing the extinction of all plants and animals. Neither water, carbon dioxide, nor the peculiar unions of carbon, hydrogen, and oxygen could be replaced by any other substances. There are no other compounds which have more than a small share of the qualities of fitness for living forms that are possessed by water, carbon dioxide, and the compounds of carbon, hydrogen, and oxygen. Ammonia (NH_3) is the only possible liquid substitute for water, but in ammonia the absence of oxygen is insurmountable. In place of carbon, silicon is imaginable, but quartz, the oxide of silicon, is the most inert and immovable of rocks.

Water has many unique properties that are essential to life as we know it. It is one of the most abundant substances. If the earth were a perfect sphere, water would cover it to a depth of from two to three miles. Water makes up a large part of protoplasm, — the only living substance. Water comprises eighty per cent of fishes and eighty-five per cent of apples. It is what carries food into the body, for the entrance of food is really by osmosis through the walls of the intestine, and hence food must be in liquid form. Water has the greatest surface tension of all liquids except mercury. Surface tension and density determine the height to which a liquid will rise in a capillary system. Without this high surface tension, water would not rise in soils and become available for the use of plants; as a consequence, lands would be complete deserts.

[1] Henderson, The Fitness of the Environment.

The heat capacity (that is, specific heat) of water is nearly maximal. It takes much heat to change liquid water to a gaseous state. Many animals have utilized this principle in perspiration to regulate the temperature of the body. One drop of sweat changing to gas takes from the body as much heat as is required to raise two drops to 212° F.

Carbon, hydrogen, and oxygen also have many unique properties, such as being sources of energy for metabolism. The amount of energy expended by the sun in green plants to tear apart the molecules of water and carbon dioxide and recombine them into compounds of carbon, hydrogen, and oxygen is very great. They are, however, again separated with ease into their original states in the organism, accompanied by the liberation of the original amount of energy.

The ocean of water is ideally mobile, is rich in varied dissolved substances, has a high specific heat, and is stable in physical conditions and chemical compounds, — an ideal environment for the simpler forms of organisms. The only improvement upon the ocean, as a life-supporting medium, is the circulating fluid of the warm-blooded animal. This apparently began its evolution as ocean water of early geologic times, and merely perfected those earlier conditions.

Thus the substances and habitats evolved in the inorganic realm were the varying environments with which life had to reckon, and, as we have seen, it made use of those which gave it maximum efficiency.

TOPICAL REVIEW

Evolution defined.
Evolution of the earth.
Incoming of air and water.
External forces of the earth and their work.
Internal forces of the earth and their work.
Effect of geologic sequence upon man's activities.
Summary.

CHAPTER III

ENERGY IN THE INORGANIC AND THE ORGANIC

Characters distinguishing the organic and the inorganic. Organic matter is a component part of a living plant or animal. It differs from inorganic matter in several important particulars: (1) Living organisms possess protoplasm and direct the expenditure of energy. Protoplasm is the only form of matter in which life is manifest; it is a colloid, jelly-like in appearance. In the inorganic, likewise, direction is given to the expenditure of energy in the growth of atoms, molecules, and crystals. (2) Organisms possess irritability (sensitivity), the capacity for receiving and responding to stimuli, usually in a manner useful to the organism. (3) Organisms have the power of getting rid of waste (that is, excretion), of internal repair and growth (that is, assimilation), and of reproduction. When a plant is actively growing, it breathes out much oxygen, and at other times carbon dioxide, while animals excrete carbon dioxide, uric acid, and solid waste. Minerals may repair themselves and increase in size by external additions; they cannot reproduce themselves. (4) Living organisms have through geologic time evolved from lower to higher forms. Plants and animals living during the early periods of earth history were much simpler than those living today, while the crystals formed then are exactly like those formed today. (5) In structure, organisms are heterogeneous and minerals are homogeneous. Each small portion of a mountain of marble is similar to every other portion, while different parts of a plant or animal differ in form and function. Even so simple an animal as the microscopic amœba has a nucleus containing minute granules of chromatin, the contractile vacuole, and other differentiated parts.

ENERGY IN THE INORGANIC

The inorganic and the organic thus differ in the utilization of energy. In the former the expression of energy, as seen in the growth of atoms, molecules, and crystals, is the same today as it was a billion years ago. In the organic, as seen in the various plants and animals, energy is today capable of a much wider and more varied expression than when it made its first appearance upon earth in those distant days. Molecules and crystals may be observed in process of formation in the laboratory. That atoms are now being formed "all about us, either in the stars, in the nebulæ, or in the depths of space" appears to be indicated by the work of Millikan and Cameron.[1] The cosmic rays, everywhere observable with proper instruments, appear to "constitute the announcements . . . of the birth of the ordinary elements out of positive and negative electrons."

An atom is composed of a nucleus and the surrounding negative electrons. Negative electrons are known to be simply centers of force, — of negative electricity. The nucleus of the simplest atom, hydrogen, is known as the positive electron or proton. It is considered by some physicists to be likewise simply a center of force, — of positive electricity, while others hold that this nucleus is complex and has not yet been reduced to simple energy. Various numbers and groupings of positive electrons attaching to themselves negative electrons give rise to all the known elements (90), while various combinations of these atoms result in all substances known upon the earth, the sun, and other celestial bodies.

The energy of the sun's heat, acting upon the air and water at the surface of the earth, gives rise to winds and rain. Water, acting upon the chemical combinations found upon the earth, forms, among other products, certain jelly-like particles called colloids. Protoplasm, the only living substance in both plants and animals, is a colloid composed principally of carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium,

[1] *Science*, Vol. 67 (1928), p. 401.

magnesium, and iron. The characteristics of life may have made their appearance when a colloid with the requisite chemical structural content came into existence, just as water with its unique characteristics emerges when the requisite number of atoms of hydrogen and oxygen unite. What the laws are which govern this union of elements and their structural differentiation to form protoplasm is not known, but they are doubtless associated with the great attractive powers of hydrogen and oxygen. Nor is it known why this emergence of protoplasm from an inorganic colloid occurred only in the very early stages of earth history. All lines of evidence — paleontological, anatomical, embryological — point to the conclusion that all plants and animals have descended from a common ancestral stock. Hence such simple, primal masses of protoplasm could have evolved into higher organisms but once in the history of life upon the earth.

Indications point increasingly to the conclusion that all matter is simply energy. It appears solid in certain forms because the atoms are so close together and the movements of the electrons are so rapid. In a similar manner the spokes of a rapidly revolving wheel appear continuous, and are so as far as ability to penetrate them is concerned. Energy in the inorganic realm is exhibited by the attraction of the nucleus of each atom for the electrons revolving planet-like about it, by the attraction of the atoms to form a molecule, by the attraction of molecules to form a crystal, by the force of gravitation, etc.

TABLE II. SUMMARY OF THE RELATION OF THE ELECTRON TO THE LIVING ORGANISM

Negative electron (an energy similar to negative electricity)
+ positive electron, the nucleus (possibly simply an energy similar to positive electricity)
= simplest atom (hydrogen).
Various groupings of hydrogen atoms = all (90) known atoms.
Various combinations of atoms = all substances known upon earth, sun, etc.
Sun's energy + H_2O, CO_2, etc. = wind, rain, soil, colloids, etc.
A colloid of requisite structural and energy composition = a living organism.

ENERGY IN THE ORGANIC

With the development of life it appears that a new type of energy became superimposed upon the preceding, — an energy capable of making more complex the combinations of matter already in existence. The most basic differences from the inorganic are the sensitivity of the living organism and the direction of the expenditure of energy. This energy is directed to internal repair and growth (that is, to the improvement of the individual) and to reproduction of others of its kind (the continuance of the race). Life makes use of the various kinds of energy exhibited by matter — atomic and molecular affinity, chemical attraction, the sun's heat, etc. — for the furtherance of its own ends.

Chemical messengers. In the jelly-like inorganic colloids the molecules are but feebly attracted to one another. The great amount of water in them renders the suspension of many elements easy, between which occur stimulating electric actions and reactions, — for example, between metallic and nonmetallic elements. To make orderly these discursive actions and reactions is the work of the directive energy of life. Later this energy develops agents, or go-betweens, by means of which the various parts of the body are coördinated, — made to act as a unit. Nerves are a very late development toward this end. In the earliest organisms known upon earth such interacting agents are chemical in nature and are known as chemical messengers, or catalysts.

The work of catalysts may be illustrated by the sequence of events which occurs when we begin to breathe faster upon exercising. To move the muscles for exercising, energy is necessary. To acquire this energy, oxygen unites with the stored-up food in the body. But the small amount of oxygen present in the cells is quickly exhausted upon the beginning of the exercise. To connect the muscles needing the oxygen with the lungs which can furnish it, a chemical messenger is used; for, during the millions of years of life upon our planet

before nerves had evolved, such catalysts alone unified the various parts of the organism, and, as the necessity for oxygen was present from the beginning of organic life, catalysts naturally continue doing their ancient work to this day. The catalyst for this end is carbon dioxide, a waste product in the manufacture of energy from food and oxygen. The carbon dioxide gets into the blood and, carried by it throughout the body, irritates through its acidic properties the nerve center of respiration. This nerve center immediately calls upon the muscles of respiration to work harder. The carbon dioxide is thus got rid of through the lungs, but at the same time more oxygen is acquired by the body. Briefly, food + O = kinetic energy + CO_2. The catalyst (CO_2) irritates respiratory centers and breathing is quickened. Thus not only is CO_2 thrown out of the body more rapidly, but more O is brought in. Hence food + more O = more energy.

Development and use of a reservoir of energy. Besides developing catalysts which make orderly the hitherto discursive actions and reactions in the colloid, and thus cause it to act as a unit, life had to develop a reservoir of energy suitable for tapping at will. The most available source of energy at the surface of the earth is the sun's heat. Plants have succeeded in storing this energy through the action of their green coloring matter (chlorophyll). Living green plants in the presence of sunlight separate the oxygen (O) atoms from the carbon (C) and hydrogen (H) atoms in the molecules of carbon dioxide (CO_2) and water (H_2O), and then recombine them into such molecules as starch ($C_6H_{10}O_5$) and sugar ($C_{12}H_{22}O_{11}$). Under such forms food is stored in the plant, forming a reservoir of energy ready to be used when needed. All that is necessary for setting free this stored-up energy is for the plant to take in through its breathing pores (stomata) the same amount of oxygen as it got rid of in storing up starch, sugar, etc., that is, twelve atoms of oxygen for each molecule of starch ($6\ CO_2 + 5\ H_2O = C_6H_{10}O_5 + 6\ O_2$). In other words, the kinetic energy of sunlight is transformed by

the green coloring matter of living plants into the potential energy of starch. This energy of sunlight, stored by reduction, can be released only through oxidation. The amount of oxygen required to oxidize starch in plants is the same as is needed to burn starch to the same degree in the air, that is, through combustion which generates heat. Thus the living plant utilizes the energy of the sun to draw a continuous stream of energy from the chemical elements in the earth, water, and atmosphere.

Every acre of ground in the temperate region receives, during an average ninety-day growing season, sun energy equivalent to 1476 tons of coal. Of this amount a 50-bushel yield of wheat to the acre (a very high figure) is an energy equivalent of less than two thirds of a ton of coal (Spoehr). Evidently the scientist of the future must work out methods for the capture and storage of a larger percentage of this solar energy.

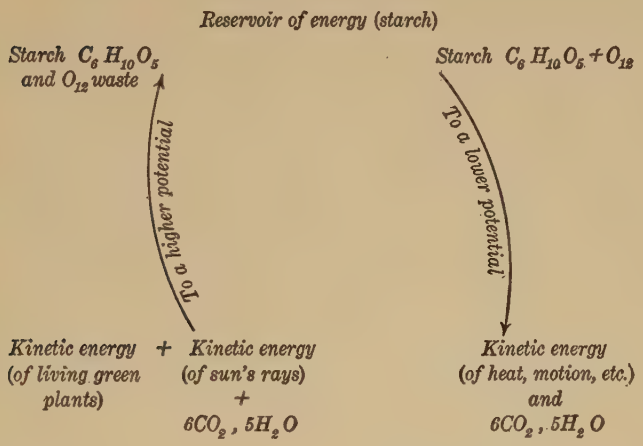
In the tables below, starch alone is considered as the reservoir, for the sake of simplicity. When energy is needed by a plant or an animal, two molecules of starch ($C_6H_{10}O_5$) are combined with one molecule of water; that is, $2(C_6H_{10}O_5) + H_2O = C_{12}H_{22}O_{11}$ (sugar).

TABLE III. DEVELOPMENT (ABOVE) AND UTILIZATION (BELOW) OF A RESERVOIR OF ENERGY

Kinetic energy of sun's rays	+ Chlorophyll of living green plants	+ 6 CO_2 + 5 H_2O =	$C_6H_{10}O_5$, starch, a reservoir of energy, + O_{12}, waste	
Living plant or animal or fire	+ Potential energy of starch, $C_6H_{10}O_5$	+ O_{12}, derived through pores of plant, or lungs of animal, or draft of stove	=	Kinetic energy of heat or work + 6 CO_2 + 5 H_2O

The two equations in Table III are often combined into one (Table IV) to emphasize the potential energy of the reservoir. The change from kinetic to potential energy may be crudely compared to the pumping of water into a standpipe on a hill. This water may then be piped down the hill, that is, to a lower potential, but in so doing the energy becomes kinetic.

TABLE IV. THE CYCLE OF CARBON AND WATER



SUMMARY OF EVOLUTION OF THE EARTH'S SURFACE COMPARED TO ORGANIC EVOLUTION

In both the inorganic and the organic, change results from the instability of the forces within the body and the action of the forces from without. The loss of water and gas from within the earth necessitates its shrinkage under gravity, and since the outer rocks cannot be accommodated to this lessened diameter, their folding into mountains takes place. For the same reason an apple, in drying, becomes wrinkled at the surface. In both the earth and the organisms there results, from the instability of the forces within, the development of new forms — new lands, new species — which, when acted upon by the forces from without, pass from this youthful stage through maturity to old age.

The evolution of the uplifted young lands into the scenic beauty of late youth and maturity and the monotony of old age is largely due to the expenditure of the energy of falling water, made potential through the lifting power of the sun's energy. The work of erosion is directed by the earth's gravity

and the inherent characteristics of the rocks over which the water flows. The result is a more deeply eroded land and the exhaustion of the potential energy of the water. The water is again raised by the sun's energy into the air and again, as falling water, performs more erosion. At the same time the eroded sediment is deposited where in time new mountains may arise.

TABLE V. RESEMBLANCES IN CAUSE AND EFFECT IN EVOLUTION OF THE EARTH'S SURFACE AND IN ORGANIC EVOLUTION

Young lands and young groups of organisms have of course been subject to the external forces throughout their slow evolution to their present stage. A region is old when nearly all the land has been removed to below sea level; an organic group, such as a genus, is old when nearly all its species are extinct

	Causes	Effects	Examples
Evolution of Earth's Surface	Forces within the earth (Internal heat and gravity acting upon surface rocks, following loss of water, gas, etc.)	Elevation of new lands	Young land (Coast Range of North America)
	Forces outside the earth (Sun's heat and gravity of earth acting upon water and air)	Reduction of lands and development of varied scenery	Mature lands (Rocky Mountains) Old lands (Central Massachusetts before the last Glacial Period)
Evolution of Plants and Animals	Forces within plants and animals (Chemical and unknown forces)	Development of new characteristics, organs, species, etc.	Young groups (Sparrows, asters)
	Forces outside plants and animals (Climate, food supply, enemies, etc.)	Elimination or changed use of organs, etc.; also destruction of organisms	Mature groups (Cat family, oaks) Old groups (Elephant, sassafras, Sequoia)

The living green plant, corresponding to the land in the example from the inorganic, develops the potential energy of starch by the action of the sun's energy upon water and carbon dioxide, etc. This is transformed by the chemical action of

oxygen with the carbon of starch (corresponding to the directing force of gravity in the example above) and by the inherent character of the plant. The result is increase in size (not decrease, as above) and the development of seeds through which more of its kind are produced, as well as the return of the water and carbon dioxide to the atmosphere.

The organic differs from the inorganic not only in the expenditure of energy but also, especially, in the result of the forces within in their operation throughout geologic time. The young lands, whether raised in the Paleozoic or in the Cenozoic, are the same. Each may pass through youth, maturity, and old age, but each succeeding youthful land is like its predecessor. There is no advance. Similarly, a crystal of calcite or of any other substance, formed during any of the older periods of earth history, is similar in all respects to one formed today. In the organic, however, the species evolved in the Cenozoic are always higher (that is, more complex), class for class, than those evolved during the older periods of earth's history.

TOPICAL REVIEW

Characters distinguishing the organic and the inorganic.
Energy in the inorganic.
Energy in the organic:
    Chemical messengers (catalysts);
    Development and use of a reservoir of energy.
Summary of evolution of the earth's surface compared to organic evolution.

CHAPTER IV

DIVERGENCE OF LIFE INTO PLANTS AND ANIMALS

All higher forms of life are dependent for their existence upon the possession of a reservoir of energy which can be drawn upon at will. We can get some idea of the amount of energy used by organisms by noting the great number of seeds developed by a plant, or by watching a child at play or a butterfly in flight.

It is obvious that, if we had been given the problem of starting life upon the surface of this earth, our first care, after supplying the impetus with which to set life moving, would have been to find a continuous source of energy capable of being utilized for storage in reservoirs, which must in turn be suitable for tapping easily when needed. We should soon have found that the only practicable source was the light of the sun. The problem then would have been to convert the sun's rays into a form suitable for storing and for tapping at will. This problem life has solved through the agency of chlorophyll, the green coloring matter of plants. Chlorophyll is the material on which the sunlight works, rearranging the atoms of carbon dioxide and water into such products as starch and sugar. In other words, the kinetic energy of the sun's rays is transformed into the potential energy of starch, and in this form becomes the reservoir capable of being tapped at will for reproduction, movement, or other needs by both plants and animals.

There is considerable reason for believing that the earliest forms of life upon earth combined in themselves the power of storing up energy and of expending it in free movements. Some lowly forms, such as the free-moving, microscopic, one-celled organism Euglena, still exist which, through the presence of chlorophyll, are enabled to manufacture starch. In such a

form the plant and animal kingdoms merge their characters to such an extent that it is impossible to classify it as definitely either plant or animal.

Differences between plants and animals. Upon no other theory than the former union of the plant and animal kingdoms can we account for the difficulty of making a definition for the one which will be exclusive of the other. There are exceptions to almost every statement made in distinguishing them. If we arrange the characteristics in contrasting columns, this conclusion will be easily seen.

Plants	Animals
1. Take food from the inorganic and convert it into organic, as starch, proteids, etc. (Exceptions: fungi, bacteria, etc. live upon organic material.)	1. Feed upon organic matter.
2. Chlorophyll present. (Absent in many parasitic forms, as dodder.)	2. Chlorophyll absent. (Present in some protozoans and ascidians.)
3. Cellulose present.	3. Cellulose absent. (Present in some protozoans and very abundant in the ascidians.)
4. Without power of locomotion. (The male cells of thallophytes, bryophytes, and pteridophytes swim freely in water. Many higher plants, as the honey locust, clover, etc., have contractility prominently developed.)	4. Locomotion more or less free. (Yet a large proportion of the invertebrates, such as corals, are as immovably fixed as are trees.)
5. Eat by absorption.	5. Have mouth and digestive canal. (Some very low or degenerate forms, as the pinworm and tapeworm in the human intestine, eat by absorption.)
6. Excrete oxygen and carbon dioxide.	6. Excrete carbon dioxide and urea.
7. Have unlimited growth (except many fungi, etc.).	7. Have limited growth (except colonial sponges, corals, etc.).

Characteristics common to plants and animals. To the exceptions in a definition of plants and animals just noted must be

added some characteristics which they possess in common. (1) The only living substance of each is protoplasm, similar in chemical composition and appearance. (2) Also, in each the unit of structure is the cell, — a bit of protoplasm containing a nucleus and surrounded by a cell wall. In plants the latter is usually cellulose; in animals it is usually a softer substance. (3) In both, growth proceeds by fission, — the division of a cell into equal halves. (4) This division is accompanied in both plants and animals by a process known as mitosis (karyokinesis). During this the chromatin fibers of the nucleus split longitudinally, the halves going to opposite sides of the enlarged cell, which then divides into two (Fig. 13). During this division each half of the chromatin gradually forms itself into the nucleus of the new cell. (5) Both plants and animals use oxygen for growth and the various organic activities. (6) To these similarities may be added the fact that both plants and animals respond to external stimuli, are affected by narcotics, become fatigued after repeated stimuli from which they recover upon rest, and upon death cease exhibiting these responses.

Divergence of plants and animals. If, as this similarity indicates, both organic kingdoms were, in the early days of earth history, united, the two lines diverged in subsequent evolution (Fig. 1). Plants have evolved along the line of energy storing; animals, along that of using this stored-up energy in free movements. It is accordingly better to define these two groups of organisms by the characters upon which each lays special emphasis. Plants lay emphasis upon immobility; animals, upon mobility. If the two kingdoms are defined thus, with the attendant consequences, the following diverse conditions result. Plants, in taking to a life of energy transformation, needed a constant supply of sunlight; they became immovably attached to the earth and developed hard parts (cellulose or woody fiber) for the protection of the soft protoplasm. As a result of this protection, stimuli from the external world could penetrate with great difficulty. Animals, on the

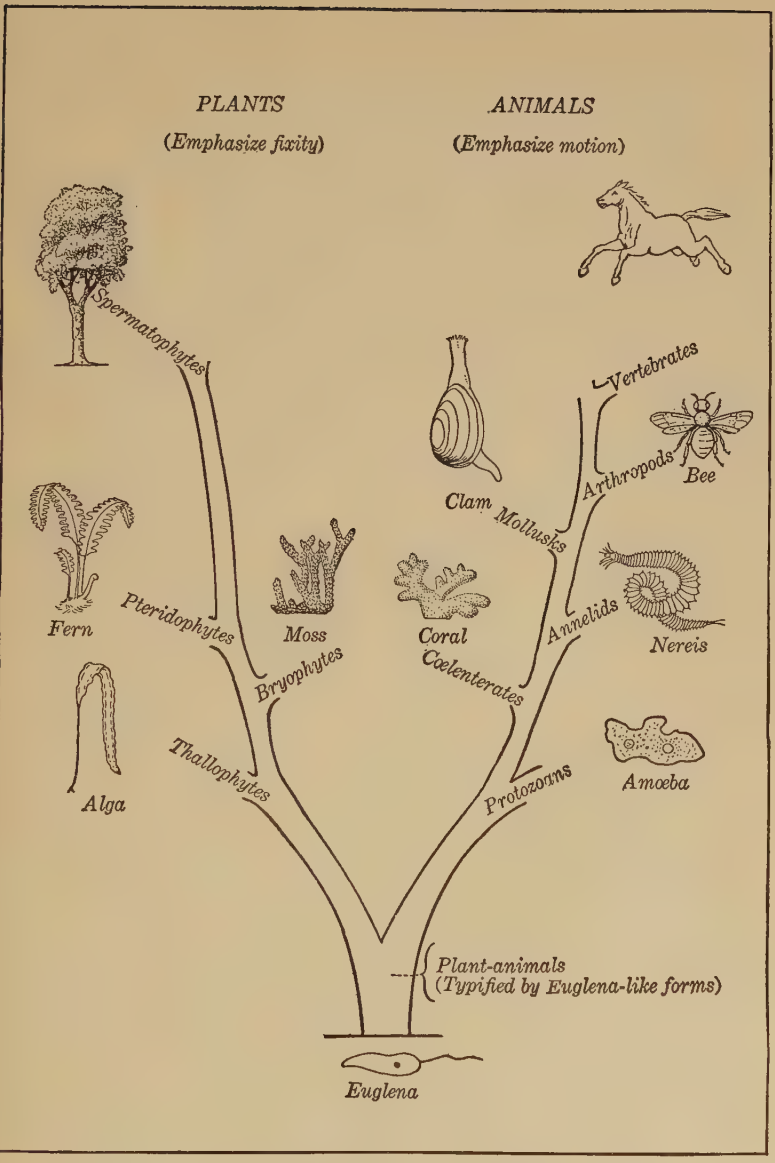


Fig. 1. Divergence of early life into plants and animals

other hand, in taking to the more hazardous life of searching for manufactured food, had to remain more or less free; because of this necessity for continued movement they could not surround themselves completely with a hard skeleton. Consequently stimuli from the external world could penetrate with comparative ease, and as a result these stimuli have fostered the development of a higher and higher consciousness, with all its attendant nerves and body organs.

LIMITATION OF LIFE UPON EARTH

Life, as it exists upon earth, is limited to temperatures between 32° F., at which protoplasm ceases to move, and 170° F., at which it coagulates. In other words, protoplasm, the only living substance in plants and animals, can move and grow only if the temperature remains between 32° F. and 170° F. Warm-blooded animals may live where it is colder than this, but since all animals are in the final analysis dependent upon plants, they must cease to exist when plants do. Yet, thus limited as to temperature, life had persisted continuously through many millions of years, giving emphatic evidence to the fact that the temperature of the entire earth has never, since the establishment of life upon earth, fallen below 32° F. or risen above 170° F. In duration life is limited to the period between the early fiery mass of the primitive earth and the future frigid earth when the sun shall have ceased to give forth heat. It is only during this period — comparatively brief, though it may be billions of years in length — that the presence of air, water, and the requisite temperature permits the existence of such life as we have upon earth today.

TOPICAL REVIEW

Differences between plants and animals.
Characteristics common to plants and animals.
Divergence of plants and animals.
Limitation of life upon earth.

CHAPTER V

CLASSIFICATION OF ORGANISMS

GENETIC CLASSIFICATION

The separation of organic life into plants and animals was, as we have seen, due to the unconscious choice of the early organisms. Those specializing in the storage of energy received from the sun are the plants, while those that only utilized these reservoirs of energy are the animals. Both these groups continued to differentiate in their particular environments until the present great variety of forms has resulted.

Animal life. The animals diverged into twelve great groups, or phyla. The phylum Protozoa includes the simplest animals. Each consists of a single cell of protoplasm, usually microscopic in size, with or without hard parts. They occur in both marine and fresh waters and as parasites in many different kinds of animals.

Phylum Porifera (the sponges). This phylum includes the simplest of the many-celled animals. Like the Protozoa, they are aquatic in habitat. Food is captured and digested by individual cells as among Protozoa, while other cells secrete spicules or fibers which form support and protection for the entire animal. This divergence of function among the cells marks a beginning in subdivision of labor.

Phylum Cœlenterata. The next stage in advance is seen in such forms as the coral and jellyfish. The body is typically cup-shaped, with the inner layer of cells specializing in digestion, the outer in protection and movement. Movement is largely confined to the arms (tentacles) surrounding the opening of the cup. In these forms many of the outer layer of

cells are elongated, some of which have specialized in contractility and are known as muscles, while others, specializing in sensitivity, are called nerves. Digestion, secretion of hard parts, contractility, and sensitivity — functions present in and performed by each single-celled protozoan animal as a whole — are among the cœlenterates characteristic of different cells. Under this specialization each act is performed more efficiently and more quickly.

Various groups of animals developed a wormlike body. Many of these are parasitic. They are now grouped into four phyla. Phylum Platyhelminthes (flatworms) includes those whose body is flattened from above downward. The liver fluke, parasitic in sheep, and the tapeworm, parasitic in man, belong here. Phylum Nemathelminthes (threadworms) includes forms with long, cylindrical, unsegmented bodies, such as the pinworms or roundworms from the intestine of man. Phylum Trochelminthes (wheelworms) comprises forms with the anterior end surrounded by cilia, by means of which it moves. Rotifers, the most common examples, are microscopic in size. Phylum Annulata (ringworms) includes those which have an elongate segmented body. Here belong most of the well-known forms, such as the common earthworm.

Phylum Echinodermata. This phylum includes those individuals in which protection is attained by the secretion of small calcareous plates embedded in the skin. All are ocean dwellers. The three primitive classes, including the crinoids, were sessile, living on the small particles of food urged into the centrally placed mouth by the cilia which line grooves upon the arms. The other four classes, which include the starfish and sea urchins, are free-moving and go in search of food.

Phylum Molluscoidea. The molluscoids are a group of animals in which the degree of subdivision of labor among the cells of the body is somewhat comparable to that of the echinoderms. In these, however, the protective secretion, usually of lime, is external. In the class Brachiopoda the animals are

Table VI. Tabular View of the Animal Kingdom

Phyla and classes are arranged from the simple and more primitive (below) to the higher and more complex (above)

Phylum		Class	Known Range	Common Name or Living Example
XII. Chordata	VERTEBRATA	Mammalia	Triassic to present	Mammals
		Aves	Jurassic to present	Birds
		Reptilia	Pennsylvanian to present	Reptiles
		Amphibia	Devonian to present	Amphibians
		Pisces	Silurian to present	Fish
		(?) Ostracodermi	Ordovician through Devonian	Shield fish
		Cyclostomata	Devonian (?) to present	Lamprey eels
		Acrania	(Fossil record lacking)	Amphioxus
		Urochorda	(Fossil record lacking)	Ascidians
		Adelochorda	(Fossil record lacking)	Balanoglossus
XI. Arthropoda	INVERTEBRATA	Insecta	Pennsylvanian to present	Insects
		Arachnida	Cambrian to present	Spiders
		Myriapoda	Devonian to present	Centipedes
		Onychophora	Cambrian (?) to present	Peripatus
		Crustacea	Cambrian to present	Lobsters
X. Mollusca		Cephalopoda	Cambrian to present	Nautilus
		Scaphopoda	Ordovician to present	Tooth shells
		Gastropoda	Cambrian to present	Snails
		Pelecypoda	Cambrian to present	Clams
		Amphineura	Ordovician to present	Chitons
IX. Molluscoidea		Brachiopoda	Cambrian to present	Brachiopods
		Phoronida	(Fossil record lacking)	Phoronis
		Bryozoa	Ordovician to present	Bryozoans
VIII. Echinodermata		Holothuroidea	Cambrian to present	Sea cucumbers
		Echinoidea	Ordovician to present	Sea urchins
		Ophiuroidea	Ordovician to present	Brittle stars
		Asteroidea	Cambrian to present	Starfish
		Crinoidea	Ordovician to present	Sea lilies
		Blastoidea	Ordovician to Permian	Sea buds
		Cystoidea	Cambrian to Permian	Cystoids
VII. Annulata VI. Trochelminthes V. Nemathelminthes IV. Platyhelminthes		Classes are omitted	Cambrian to present (Fossil record lacking) Cambrian (?) to present Pennsylvanian to present	Segmented worms Wheelworms Threadworms Flatworms
III. Cœlenterata		Ctenophora	(Fossil record lacking)	Comb jellies
		Anthozoa	Proterozoic to present	Corals
		Scyphozoa	Cambrian to present	Jellyfish
		Hydrozoa	Cambrian to present	Hydrozoans
II. Porifera		Spongiæ	Proterozoic to present	Sponges
I. Protozoa		Infusoria	(Fossil record lacking)	Infusorians
		Sporozoa	(Fossil record lacking)	Gregarina
		Sarcodina	Proterozoic to present	Amœba
		Mastigophora Choanoflagellata Flagellata	Cretaceous (?) to present	Euglena
		Mycetozoa (*Myxomycetes*)	(Fossil record lacking)	Slime molds

separate individuals with an average width of less than one inch. They secrete an external skeleton of two pieces, or valves (somewhat similar to those of a clam or an oyster), which, when fully closed, protect the soft parts. In the class Bryozoa the animals live in colonies of hundreds of individuals. Each individual, averaging about one millimeter in width, secretes a cuplike skeleton around its base. The resultant colony looks much like a colonial coral, but with a much smaller individual cup and a much higher type of living organism.

Phylum Mollusca. Members of this phylum are in general free-moving individuals, usually secreting for protection an external skeleton of lime. The snail, oyster, and mussel are well-known examples. The highly organized body has a stomach, intestine, and liver for digesting food, kidneys for the excretion of liquid waste, heart and blood vessels for the circulation of blood, gills for respiration, and a nerve ring around the esophagus giving off nerve cords which coördinate the various bodily activities. Of the five classes within this phylum the Pelecypoda include the fresh-water mussels and the marine clam, oyster, and scallop; the Gastropoda, the land snail and slug, and numberless fresh-water and marine snails; the Cephalopoda, the marine Nautilus and squids.

Phylum Arthropoda. This is another very successful group of animals, developed along the pattern of the segmented worms, that is, with a transversely segmented, elongate body and a central nervous system, or brain, in the front end of the body, from which a nerve cord extends backward, connecting and unifying all the segments. In addition to this the arthropods have an external protective skeleton of a horny substance known as chitin. This is present in a rather pure state in the insects, while in many of the crustaceans, such as the crab and lobster, it is greatly thickened and hardened by an addition of lime. Since this skeleton surrounds the body completely, growth can take place only through a succession of molts. As a result the animals must remain

comparatively small. Because of the ease with which this external skeleton may be modified the members of this phylum are very abundant in every environment, — in the ocean, in fresh water, on the earth, and in the air. The class Crustacea is largely made up of water dwellers, but the sow-bug and pill-bug are terrestrial. The fresh-water forms include the crayfish; the ocean dwellers, the crab and lobster. The majority are free-moving, but the barnacles are sessile. In the class Myriapoda, the centipedes have one pair of legs to each body segment; the millipedes have two pairs. The class Arachnida number such marine forms as the horseshoe crab (Limulus) and such land forms as the spiders and scorpions. The class Insecta is a very successful group, as is shown by their abundance. There are four times as many species of insects as there are of all other animals put together.

Phylum Chordata. In this phylum are included all animals with a backbone, from fish to man. The chordates and arthropods differ radically in the position of their supporting structures. In arthropods this skeleton is external, upon the inside of which the muscles are fastened; in the chordates the skeleton is internal, with muscles attached to its exterior surface. The most primitive form of this internal skeleton is the notochord (or chorda). This gives the name to the phylum. It is present throughout life in the sub-phyla Adelochorda and Urochorda and in the most primitive division of the sub-phylum Vertebrata, the class Acrania (example, Amphioxus). In all other vertebrates (the Craniata, that is, those possessing a skull) the notochord is present in its entirety only in the embryo; it is later replaced partly or wholly by cartilage and bone. This type of internal skeleton, reënforced in higher forms by the addition of skull and limbs, has been one of the chief elements in making this phylum dominant in all environments, from abyssal oceans to mountain tops. Under the craniate vertebrates are included, in ascending order, the classes Cyclostomata (lamprey eels), Pisces (fish, living at all ocean depths and in fresh waters), Amphibia

(salamanders, frogs, toads, with eggs laid in fresh water where the young stage is passed and an adult stage passed upon land), Reptilia (lizards, alligators, turtles, snakes, covered with scales, with eggs laid upon land, and consequently no youthful tadpole stage), Aves (birds, covered largely with feathers), Mammalia (kangaroos, armadillo, cat, horse, with young nourished for a time by a secretion of milk).

Plant life. In this division are those organisms which specialize in the storage of solar energy. These are represented today by groups in various stages of development and living in various environments. Plants are the sole primary source of energy for animals. Of the four phyla into which they are usually divided the phylum Thallophyta (thallus plants) includes the simplest forms. Here are the Protophyta, such one-celled plants as bacteria, diatoms, and some algæ, and also such many-celled forms as our abundant seaweeds (algæ) and fungi. The silica-secreting, microscopic diatoms are most abundant, floating at and near the surface in marine and fresh waters of the temperate zone, and are the primary, but indirect, source of food for pelagic fishes. Algæ are usually very abundant in fresh and normal salt waters down to the limit of the penetration of light at about one hundred fathoms. Fungi comprise the one class of plants all of whose members live upon other plants or animals. They cause decay. Common examples are the bracket fungi on trees, toadstools, mushrooms, molds, mildews, and yeast. Lichens, representing a close union between algæ and fungi, are able to live upon the surface of rocks where nothing else can subsist.

Phylum Bryophyta (moss plants). In these a subdivision of labor among the many body cells has brought about the development of outgrowths, upon the ends of which the reproductive spores are produced. Of the two classes included, that of the more primitive Hepaticæ is represented by the world-wide genus Marchantia, and that of the Musci, by the common and abundant mosses.

Table VII. Tabular View of the Plant Kingdom

Phyla and classes are arranged from the simple and more primitive (below) to the higher and more complex (above)

Phylum	Class	Known Range	Common Name or Living Example
IV. Spermatophyta (seed plants)	Angiospermæ — Dicotyledones	Lower Cretaceous to present	Oaks
	Angiospermæ — Monocotyledones	Lower Cretaceous to present	Grasses
	Gymnospermæ — Gnetales	(Fossil record scant)	Ephedra
	Gymnospermæ — Coniferales	Permian to present	Pines
	Gymnospermæ — Ginkgoales	Permian to present	Ginkgo
	Gymnospermæ — Cycadales	Triassic to present	Cycads
	Gymnospermæ — Cycadeoidea	Permian to Cretaceous	Cycadeoids
	Gymnospermæ — Cordaitales	Devonian to Permian	Cordaites
	Gymnospermæ — Cycadofilicales	Devonian to Jurassic	Neuropteris
III. Pteridophyta (fern plants)	Lycopodiales	Devonian to present	Club mosses
	Sphenophyllales	Devonian to Permian	Sphenophyllum
	Equisitales	Devonian to present	Horsetails
	Filicales	Devonian to present	Ferns
II. Bryophyta (moss plants)	Musci	Mississippian (?) to present	Mosses
	Hepaticæ	Silurian (?) to present	Liverworts
I. Thallophyta (thallus plants)	Fungi	Silurian to present	Fungi
	Diatomeæ	Jurassic to present	Diatoms
	Algæ	Pre-Cambrian to present	Seaweeds
	Myxomycetæ	(Fossil record lacking)	Slime molds
	Schizophyta — Blue-green algæ	Archeozoic to present	Blue-green algæ
	Schizophyta — Bacteria	Proterozoic to present	Bacteria

Phylum Pteridophyta (fern plants). One of the most prominent features in this phylum showing advance over the preceding is the presence of fibrovascular bundles. These are groups of elongate cells arranged end to end, extending from the extremity of the roots to the tips of the leaves. They perform for plants a function similar to that of the skeleton of the chordates, — that of an internal supporting structure. They not only enable the plant to stand upright and to grow tall, but also furnish channels for the more rapid flow of the sap. The progress of sap through the thallophytes and bryophytes is comparable to that of water through a swamp, while it flows through pteridophytes and spermatophytes as a stream through pipes. Ferns, club mosses, and horsetails represent the three principal orders of the pteridophytes.

Phylum Spermatophyta (seed plants). The development of seeds has enabled representatives of this phylum to spread into environments, such as desert regions, into which other forms could not enter. The grasses of the prairies and the cacti of the warmer deserts are familiar examples. The seed plants are divided into two classes. The more primitive of these, the Gymnospermæ, include the cone-bearing trees (pine, hemlock, spruce). The Angiospermæ, the flowering plants, in which the seed possesses an added protection, include the majority of the plants utilized by man, — flax, cotton, wheat, potato, strawberry, and the apple, walnut, and orange trees.

Examples of genetic classification. The basis for the genetic classification of organisms is similarity of fundamental structures. The organs of digestion, of assimilation, of excretion, and of respiration, the parts of the nervous system, and the structures of body support are fundamental and are accordingly of greater importance than the more easily modifiable general contour of body or the character of the ends of limbs. The classification of an organism, proceeding from the general to the particular characteristics, is thus a brief way of describing it. The following classifications of man, the house cat, and the potato are illustrations.

	Man	House Cat	Potato
Kingdom	Animal	Animal	Plant
Phylum	Chordata	Chordata	Spermatophyta
Class	Mammalia	Mammalia	Angiospermæ
Order	Primates	Carnivora	Polemoniales (Phlox order)
Suborder	Anthropoidea	Fissipedia	
Family	Hominidæ	Felidæ	Solanaceæ
Genus	Homo	Felis	Solanum
Species	sapiens	domestica	tuberosum

BIONOMIC CLASSIFICATION

All organisms may likewise be classified according to the manner and place of their life. This separates them into three great groups: plankton (floating organisms), nekton (swimming or flying organisms), and benthos (bottom dwellers).

Plankton. The majority of plankton are microscopic in size. Their movement is almost entirely due to currents of air or of water. The marine forms, however, can rise to the surface and can sink to a depth of from fifty to one hundred and fifty fathoms. The plankton include not only such permanently floating organisms as diatoms and pteropods but the youthful stages of many benthonic organisms, such as spores and seeds of plants and the larvæ of animals. The adults of many different kinds of plants and animals, when carried by floating trees etc., are exceptional additions to this floating group. Such a temporary planktonic existence forms an important means to a change in habitat.

The marine plankton include such plants as diatoms, and among animals many protozoans, crustaceans (many phyllopods, copepods, and ostracods), pteropods among the mollusks, and the larvæ of benthonic animals. It is as larvæ that normally benthonic organisms are distributed. These animals include sponges, cœlenterates, echinoderms, molluscoids, and the majority of mollusks and crustaceans. They float about in the upper levels of the ocean in huge swarms, a sport of the waves and currents. After an existence here of a few

hours or a few days according to the species, they sink to the bottom and develop into the benthonic adult.

Fresh-water plankton are present in all fresh-water ponds, lakes, and streams. They include many microscopic plants, especially diatoms and desmids, protozoans, many phyllopod, copepod, and ostracod crustaceans, and the larvæ of benthonic plants and animals. Kofoid has shown in his studies of the Illinois River that the number of planktonic organisms averaged, during the year, 750,000,000 for each cubic meter; 720,000,000 of these were plants and 30,000,000 were animals. The maximum number, 4,000,000,000 per cubic meter, occurred early in the month of May.

There are no permanent terrestrial plankton, but many unicellular plants, such as bacteria and the spores and seeds of plants, are carried by winds.

Nekton. The most typical aquatic nektonic animals are the fish, abundant both in the sea and in fresh waters. The marine nekton also include such cephalopods as the squids and such degenerate mammals as the whales and seals. The fresh-water nekton also include the tadpoles. There are no permanent terrestrial nekton, for all return more or less frequently to the earth. Among these may be numbered birds, such mammals as bats, and such arthropods as some insects and spiders.

Benthos. The bottom dwellers are of two general types, the sedentary and the vagrant. The sedentary are attached to the bottom and are dependent for food on those inorganic substances and organic particles which are brought within reach by currents and gravity. The vagrant move more or less freely over the bottom in search of food. These are often partly nektonic.

The marine sedentary benthos include sponges, the majority of cœlenterates, crinoids, molluscoids, barnacles, algæ, and many protozoans and worms. The vagrant benthos include starfish, sea urchins, many gastropods, and crustaceans.

Among the fresh-water benthos are algæ and many higher plants, many protozoans, sponges, hydrozoans, bryozoans, and

worms, especially rotifers. The vagrant include mollusks, worms, and crustaceans. The crayfish is both vagrant benthonic and nektonic.

The terrestrial sedentary benthos are especially represented by the plants that we see about us; the vagrant, by the animals, including man.

TOPICAL REVIEW

Genetic classification:
- Animal life;
- Plant life;
- Examples of genetic classification.

Bionomic classification:
- Plankton;
- Nekton;
- Benthos.

III

EVIDENCES OF EVOLUTION

Frequently consider the connection of all things in the universe and their relation to one another. For in a manner all things are implicated with one another, and all in this way are friendly to one another; for one thing comes in order after another, and this is by virtue of the active movement and mutual conspiration and the unity of the substance.

MARCUS AURELIUS

INTRODUCTION

It is the postulate of the evolution hypothesis that the vegetable and animal forms that people the earth are the descendants of past forms in an unbroken succession of relationship, and that causes both within the organism and in its environment are constantly operative to modify it, so that those members of the succession which are most distant in time and those which are farthest removed in geographical environment will differ most from each other. There are many evidences of this more or less close relationship of living species to one another and to the past species of the earth as preserved in the fossils of its strata. Among the most important of such evidences are the following:

1. Indications of descent of species from preceding species, and their modification in time as shown by ***paleontology.***

2. Indications of the relationship of living species to one another as shown by ***comparative anatomy.***

3. Race memory as shown in the development of the embryo in the ***ontogeny*** *of each organism.*

4. The fact of variation and the selective influence of the environment as shown in ***geographic distribution.***

The evidences for the evolution of organisms are of the same character as those that reveal the development of such ancient civilizations as those of India, Greece, and Rome, and their descent from a common ancestral stock. Our knowledge of the development of these civilizations is based on the excavation and interpretation of such archeological remains as tools, pottery, coins, statues, and cities, — objects which correspond to the fossil remains of past organic life.

A comparison of the remains found at lower levels of the excavations with those occurring at higher levels gives evidence of change, as does the comparison of fossils from lower and higher strata. The deciphering of inscriptions on coins and monuments corresponds to the interpretation of a bone or a shell. Similarly, a comparison of the languages and customs of the living descendants of these dead civilizations with one another and with those of their ancestral stock reveals mutual relationship and common descent in a manner analogous to that of comparative anatomy in revealing relationship among organisms. When archeological facts are tabulated, it is found that they may be interpreted only upon

the hypothesis that the now widely separated languages and peoples above cited are the descendants of one very ancient language and people, and that their present differences are due to a migration of parts of the original stock into separated regions, where, under varying environments, they developed increasing differences in arts and languages.

The same explanation of descent from a common ancestral stock is the logical interpretation when the species of any large group of plants and animals are tabulated. When the concept of organic evolution is used as a working hypothesis, this array of observed phenomena becomes intelligible. All the facts of paleontology, comparative anatomy, embryology, and geographic distribution of the group become consistent.

The evidences point not alone to the fact that evolution ***has taken place.*** *Evolution may be seen* ***taking place*** *spontaneously in nature today, though the changes are so slight that they remain unnoticed unless they are carefully and intelligently sought. It is also taking place more rapidly through the agency of man in the development of new fruits, flowers, and domestic animals, through selection and segregation of the most desired variations as they arise in any group.*

CHAPTER VI

EVIDENCE OF EVOLUTION FROM PALEONTOLOGY

Paleontology is the science which deals with the life of past periods of earth history as recorded in the fossils found in the rocks of those periods.

A fossil may be defined as the remains of a plant or animal, or the record of its presence, preserved in the rocks of the earth. In the words of Huxley, "Fossils are only animals and plants which have been dead rather longer than those which died yesterday."

Fossil remains of plants and animals include individuals in which both hard and soft parts are preserved, such as the elephants frozen in the tundras of northern Siberia thousands of years ago, and the incomparably more numerous individuals of which only the hard skeletal parts are preserved. Very frequently these hard parts have been more or less completely replaced by foreign mineral matter, as in the case of silicified wood. Often only the record of the former presence of organisms is preserved in the rocks. Such records may be imprints of leaves, shells, and so forth, footprints and burrows of animals, bird nests, and human implements.

Evidence of evolution from paleontology. The evidence of evolution as supplied by paleontology can be considered under six heads.

1. *The farther down we go in the earth's strata the more and more unlike the present forms do the fossils found there become.* The mud which is being carried down this year and deposited in a lake or ocean rests upon that which was deposited last year, while that rests upon the preceding year's deposit, and obviously so on back, year before year, through centuries and millennia.

TABLE VIII. SUBDIVISIONS OF EARTH HISTORY AND THEIR AGE IN YEARS ACCORDING TO MEASUREMENTS OF TIME BASED ON RADIOACTIVITY [1]

ERA	PERIOD			DOMINANT ANIMALS	MILLIONS OF YEARS
CENOZOIC	Quaternary		Holocene (the present) Pleistocene (world-wide glaciation)	Age of Man	1
	Tertiary	Late	Pliocene Miocene	Age of Mammals	7 19
		Early	Oligocene Eocene Paleocene		35 55
MESOZOIC	Late		Upper Cretaceous Lower Cretaceous	Age of Reptiles	95 120
	Early		Jurassic Triassic		155 190
PALEOZOIC	Late		Permian (world-wide glaciation) Pennsylvanian } Carboniferous Mississippian }	Age of Amphibians	215 250 300
	Middle		Devonian Silurian	Age of Fishes	350 390
	Early		Ordovician Cambrian	Age of Invertebrates	480 550
PROTEROZOIC	Late		(World-wide glaciation at close)	Age of Primitive Invertebrates	1000
	Early				
ARCHEOZOIC				Age of one-celled plant-animals	2000 +
COSMIC	(From the nebula to the solid earth)			No life	

[1] The last column gives the estimated time, in millions of years, since the periods began.

In the Back Bay district of Boston the latest deposits, extending in places from the present day back to about the year 1868, are due to human agencies and form a fill blotting out the old bay. This averages 18 feet in thickness (Table IX). It rests upon muds brought into the bay by streams during the preceding years back to the earliest colonial days, for this deposit, usually less than 1 foot in thickness, contains remains of utensils and other objects used by the Bostonians of those early times. Beneath this are 8 feet of muds containing marine shells similar to those now living in the Boston harbor, and thus indicating a temperature similar to that at present. These rest upon 4 feet of muds filled with marine shells very similar to those now living off the coast of Virginia, which thus testify to a warmer temperature than that at present. These upper 31 feet of deposits in the Back Bay region are perfectly continuous; they represent an uninterrupted sequence of deposition and can be distinguished only by the fossils they contain. Beneath these muds is a variable thickness of blue clay deposited by waters from the melting glaciers during the time when these ice sheets covered the rest of northern New England. This clay rests in turn upon much older slate rock. Thus the section given in Table IX shows progressively older deposits from top to bottom; within each are remains of plants and animals which lived and died during those times, and which are progressively more and more different from the life of today as we go on down the section.

TABLE IX. LATE GEOLOGIC DEPOSITS AT BOSTON

The section represents the upper strata in the Back Bay region of Boston, Massachusetts

Holocene	Fill (by man since 1868)	18 feet
	Dark gray mud (with colonial fossils)	1 foot
	Dark gray mud (with cold-water fauna)	8 feet
	Dark gray mud (with warm-water fauna)	4 feet
Pleistocene, blue glacial clays		80 feet

In the section of rocks exposed in the Grand Canyon of the Colorado River in northwestern Arizona and to the northward (Fig. 2) is seen a much thicker succession of shale, sandstone, and limestone — the hardened mud, sand, and lime beds of ancient days. The majority of the beds are still horizontal as when laid down by the streams and ocean currents. It is thus obvious that the beds at the bottom of the section were deposited first and, successively, the ones higher and higher. Within each bed are found some remnants of the life which lived in this region while the sediment was

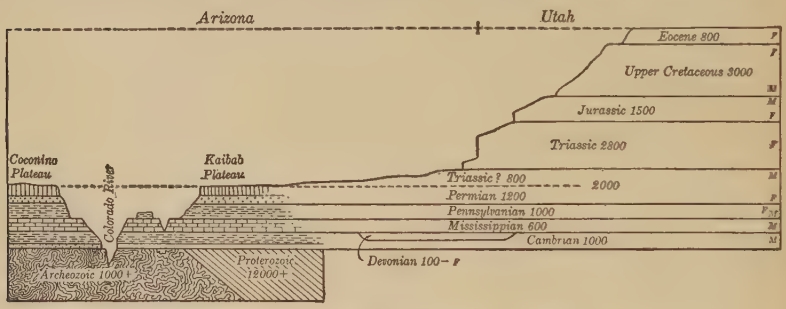


Fig. 2. Ideal section northward through the Grand Canyon of the Colorado River

The river is now cutting at a depth of one vertical mile below the bounding plateaus and almost three miles below the surface of the Eocene. The horizontal strata at the right in the figure formerly extended unbroken across the canyon area. *F*, freshwater deposits; *M*, marine deposits

being deposited. Some conception of the time consumed in the deposition may be gained by a comparison of the thickness of the Boston section of thirty-one feet and the Grand Canyon section of twenty-seven thousand feet. Such a marvelously extensive section as this which is supplied by the Colorado River furnishes in the fossil record of its strata most valuable data in the study of the evolution of life.

The most common manner in which the older beds of rock become exposed so that they may be studied consists in the folding of the originally horizontal beds into mountains and the subsequent erosion of the more elevated portions (Fig. 3).

If the erosion is deep enough, as is the case in most of the mountains of the earth today, successive beds are seen from the oldest at the center of the mountain outward (that is, upward) through progressively younger beds to the latest deposited.

At times, in the folding of the rocks to form a mountain, some beds are broken across and slip past others. Such a slip is known in geology as a fault. Faults at times carry beds several miles from their original position. But whether the displacement is little or great, evidence that a movement has

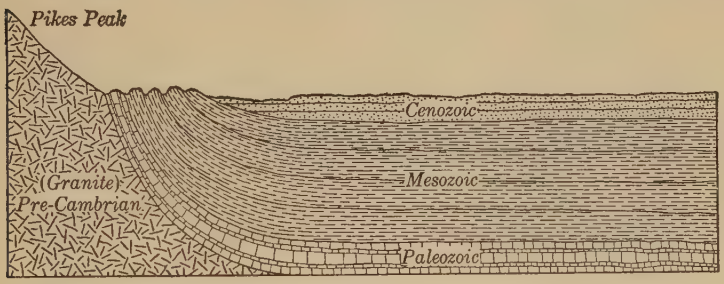


Fig. 3. Ideal section from the Front Range of Colorado eastward

taken place is usually present in contortion of the beds or in slickensides, — the smoothed, striated, and often polished fault surfaces along which slipping took place. Hence, in studying for the first time the succession of fossils in any mountain section, the series of beds which are still in their normal order is selected.

When the fossils inclosed in any such normal succession of beds are studied, it is seen that the organic remains from the higher (later) beds are most similar in form to those living today, and that they become progressively more and more dissimilar in the lower (older) beds. In the section (Fig. 3) from the Front Range of the Rocky Mountains eastward, for example, there are found, in the latest deposited beds of the Cenozoic (the Pleistocene), the American mastodon, the Columbian elephant, several species of horses, large and small

species of wolves, several species of bisons, etc. Below this, still in the Cenozoic, occur several species of the small three-toed horses, very primitive raccoons, etc. In the Mesozoic rocks there is no representative of the large-brained mammals so characteristic of the Cenozoic. In place of these there are vast numbers of the small-brained but usually huge-bodied reptiles. Such are the herbivorous land dinosaurs (Triceratops, with a length of from 20 to 25 feet and an estimated weight, when living, of 10 tons; Brontosaurus, from 60 to 70 feet long, weighing 40 tons, and Atlantosaurus still larger), the marine mosasaurs, with a length at times of 30 feet, the marine plesiosaurs, one of which, Elasmosaurus, attained a length of from 40 to 50 feet, and flying reptiles, one of which, from western Kansas (now mounted in the American Museum of Natural History), is 16 feet from tip to tip of the outspread wings and probably weighed, when alive, 25 pounds. Associated with the fossils of marine reptiles are great numbers of the highest order of fishes, the teleosts, and of invertebrates, especially mollusks. In our next great step downward in the rock series, that is, toward the median line of the Front Range, we leave the huge reptiles behind us. In these Paleozoic rocks primitive fish are present, but the abundant invertebrates are especially noteworthy. These were very different from the invertebrates of today. The most conspicuous element was the brachiopod class, the last dwindling remnant of which is meagerly represented today by some thirty species. Many groups then abundant are now extinct. These vanished groups include the subclass of trilobites among the Crustacea, the classes of cystoids and blastoids of the echinoderms, the tetracoral and tabulate orders of the corals, and the graptolite order of the hydrozoans.

A similar change from complex to simple in the form of animals is seen in descending the series of rocks in the Grand Canyon region, or in the Alps or the Himalayas. There is everywhere the same result, — the farther down the earth's strata are explored, the more and more unlike the living

forms do the fossils become. This fact has been reduced to mathematical terms in the case of the Cenozoic. Of the species of animals found fossil in the rocks of the Pleistocene period about 90 per cent are living today (Holocene); of the Pliocene, about 50 per cent; of the Miocene, about 30 per cent; of the Oligocene, about 10 per cent; of the Eocene, about 5 per cent; while in the Cretaceous there are no fossils representing species living today, though there are many genera. From the Pleistocene down to the Archeozoic the similarity of the life of the time to that of today becomes progressively more and more distant.

2. *Strata nearest to each other in superposition contain the most similar fossils, and those most separated in age contain the most diverse fossils.* The early Eocene horses had four toes to each foot; the Miocene horses had three toes, while the Holocene horses have a single toe. Of these the Eocene and Holocene horses are the most widely separated in age and are the most diverse.

The birds of the Jurassic had teeth in their jaws, claws on their wings, and a long, lizard-like tail; those of the Cretaceous had teeth in their jaws, a shorter tail, and probably no claws to their wings in the adult. The adult birds of the Cenozoic have no teeth in their jaws, no claws to their wings, and a very short vertebrated tail. The Jurassic and Cenozoic are most separated in age and contain the most diverse birds.

3. *Fossil faunas and floras succeed each other the world over in the same general sequence.* Whether in Australia, Asia, Europe, Africa, North America, or South America, the general succession of plants and animals from lower to higher rocks, wherever studied, has been found to be the same. Everywhere the trilobites, most primitive of known crustaceans, appear first in the rocks of the Cambrian period, and everywhere they disappear by the close of the Paleozoic. In these upper Paleozoic rocks, where the last survivors of the trilobites still linger, occur numerous shells of Producti, primitive insects, and huge trees of scouring rushes and club mosses. All

these are everywhere lacking in the succeeding Mesozoic strata, which abound instead in cephalopod ammonites and ancient squids (Belemnites), in land reptiles (Dinosaurs), flying reptiles (Pterosaurs), and marine reptiles. By the Cenozoic these have disappeared and been replaced by large-brained mammals and toothless birds.

As the forms are tabulated it is seen that in the early days of earth history, during which the lowest beds were laid down,

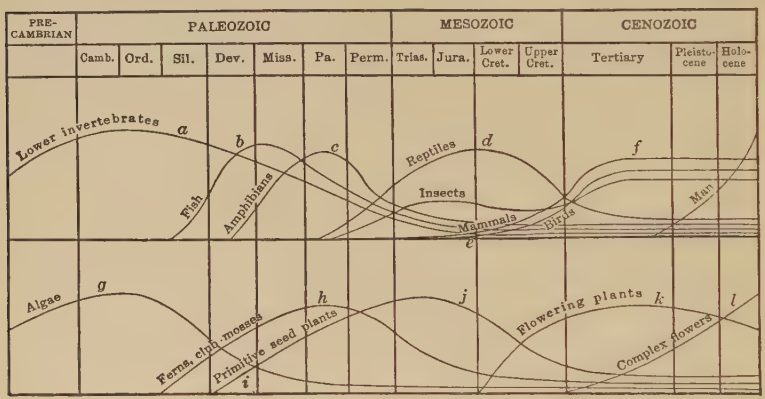


Fig. 4. The increasing complexity of life

Showing the gradual incoming of successively higher groups of animals and plants and the increasing complexity of earth's life

only water-dwelling plants and animals existed, and that, later, amphibious forms appeared, — forms which, like salamanders, lived during youth in water and during adulthood upon land. Only later did plants and animals appear which could pass their entire life upon land.

Such a tabulation shows likewise that during the earlier periods of earth history it was only the least developed plants and animals that existed. Higher and higher forms of both organic kingdoms appeared at intervals from that time to the present. Among the animals (Fig. 4) the lowest of invertebrates alone existed in the earliest periods; later there gradually appeared not only the higher invertebrates but also,

successively, fish, amphibians, reptiles, mammals, and man. This progressive succession was the same on every continent.

4. *Constant change characterizes the fossil series of organic forms.* Species of one geologic period are replaced partly or completely by other species in the next superimposed rock series. Of the thousands of known species from the Silurian rocks, for example, probably not more than a dozen are present in the middle Devonian. No Paleozoic species are known from the Mesozoic rocks.

5. *Each species, like each individual, has a shorter or longer life period, after which it perishes, never to reappear.* Of the numerous species of three-toed horses so characteristic of the mid-Cenozoic none have reappeared since their extinction in the Pliocene. The toothed birds so characteristic of the Mesozoic became extinct with the close of the Cretaceous and have not appeared since. The science of index fossils — the identification of the age of a rock by means of its fossil content — has been used for a century in mining and, more recently, in oil-well work. This science is wholly dependent upon the close identification of certain species with certain strata and upon the nonappearance of these species in later strata.

6. *The gradual development of one species into a different species is observed as later-deposited rocks are examined.* In studying the fossils found in a succession of strata from earlier to later we see many examples of a gradual change from one species into another species, and from one genus into another genus.

a. Evolution of the horse. In the succession of fresh-water strata of North America has been traced the evolution of many mammals, one of which is the horse. In these Cenozoic strata is seen the gradual change of the small four-toed horse of the early Tertiary into the larger three-toed animal, and thence into the still larger one-toed horse of today (Fig. 5). In the splint bones on each side of the single toe the present-day horse still preserves a record of its past, and during its embryonic life these splints end in distinct toes which are resorbed before birth. In the lower beds are found only small horses, about one foot high, with four toes to each foot, with

two well-developed bones in both fore leg and hind leg, with low-crowned teeth, and with the eye socket placed midway of the length of the skull. As horses from higher and higher beds are examined it is seen that they very gradually change in all these respects. The eye moves backward in the skull, the side toes become shorter and shorter until mere splints remain, and one of the bones in each fore leg and hind leg becomes

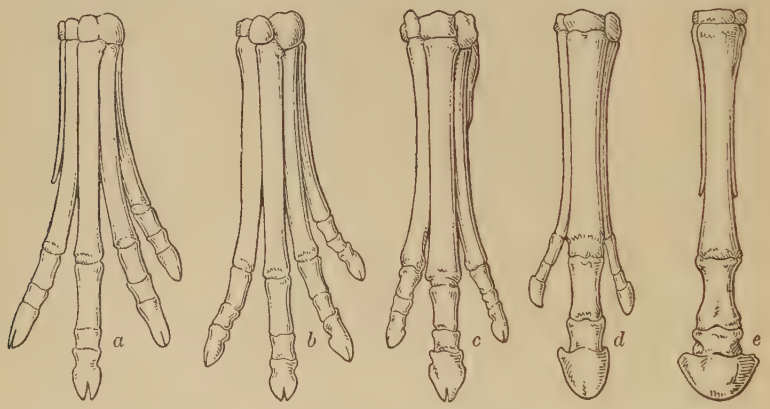


Fig. 5. Principal stages in the evolution of the fore foot of the horse

From the early Eocene Eohippus (*a*), through the later Eocene Orohippus (*b*), the Oligocene Mesohippus (*c*), the Pliocene Hipparion (*d*), to the living Equus (*e*), the foot becomes longer, the bones heavier, and the digits are reduced from four and a splint, through four, three, to one toe and two splints. (The figures are not drawn to scale)

smaller and smaller until the upper end alone remains (Fig. 7, *U*; Fig. 8, *F*). The teeth remain low-crowned until about the mid-Tertiary (at the time of the incoming of the more siliceous grasses), when they gradually develop higher crowns. Accompanying these changes the individual bones gradually increase in length, an increase which accounts for the progressively larger horses of later beds. The earlier types of horses gradually disappear after the incoming of the larger, more slender, and hence fleeter ones. Thus there are no four-toed horses in the Miocene and no three-toed horses in the Pleistocene. This change in the horse by almost imperceptible

gradations from the little Eohippus of the Eocene to the large horse of today can be explained only by evolution.

b. Evolution of the camel. A similar development upon the continent of North America during the Cenozoic Era was that of the camels. During this evolution they increased from animals as large as the house cat in the early Eocene to forms larger than the present-day Asiatic camel in the Pliocene. The early Eocene species had four toes to each foot. By the upper Eocene the side toes had become shorter than the two median ones. By the early Miocene the side toes had disappeared, while the metatarsals of the median toes were usually solidified into a cannon bone (always so in the later Miocene). In this period also the hoof was partly buried in a pad, as is evidenced by its pitted surface. Camels attained their largest size and greatest number during the Pliocene. During the late Tertiary they migrated into South America, Asia, and Africa, but died off in their original home in the Pleistocene. They persist today in the llama, alpaca, and vicuna of South America and in the camel of Asia and north Africa.

TOPICAL REVIEW

Paleontology and fossil defined.
Evidence of evolution from paleontology.

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2. Strata nearest to each other in superposition contain the most similar fossils, and those most separated in age contain the most diverse fossils.
3. Fossil faunas and floras succeed each other the world over in the same general sequence.
4. Constant change characterizes the fossil series of organic forms.
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6. The gradual development of one species into a different species is observed as later-deposited rocks are examined.

a. Evolution of the horse.
b. Evolution of the camel.

CHAPTER VII

EVIDENCE OF EVOLUTION FROM COMPARATIVE ANATOMY

Much corroborative evidence of evolution is seen in the comparison of the structures of various animals or of various plants. The deduction is that similar basic features of organization suggest a common ancestry for the organisms which they characterize.

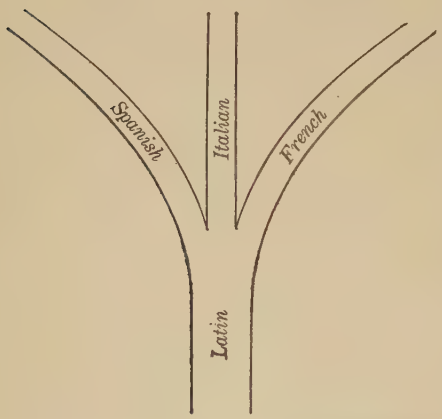


Fig. 6. Evolution of the Romance languages

This principle, namely, that unity of structural ground plan argues a common ancestry, is illustrated in the development of the Romance languages. The French, Italian, and Spanish languages possess basic features in common. The majority of the old word forms, that is, the roots of those words that have been in the languages since very ancient times, are similar, as are also the grammatical processes. That these resemblances are due to descent from a common ancestral language is indicated by the fact that each can be traced back by means of its earlier literature into the Latin of classic Rome. Largely because the Roman settlers in what are now France and Spain, and the inhabitants of Italy, came in contact with different peoples and other divergent influences, the changes in and additions to the originally common language gave rise to the distinct Romance languages of today.

Vertebrates. 1. *Bones.* In the same way similarity in the structural ground plan of the various mammals should indicate a common ancestry. Mammals are without exception characterized by the possession of an elongate supporting rod, the backbone, which is expanded anteriorly into the skull. To the backbone are attached two pairs of limbs and the ribs.

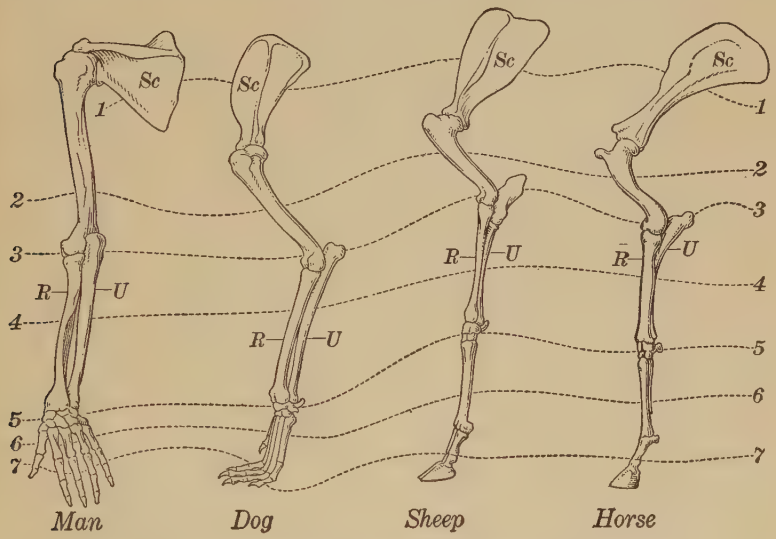


Fig. 7. A comparison of the anterior limbs of mammals

Man's relationship to other mammals is shown in the similarity of the skeletons. *R*, radius; *Sc*, scapula (shoulder blade); *U*, ulna

In Fig. 7 are shown the anterior limb bones of certain typical mammals. In each case the shoulder blade (scapula, *Sc*) (*1*) has a socket at its lower end into which fits the rounded head of the humerus (*2*), the single bone of the upper arm. This articulates at the elbow joint (*3*) with the two bones of the forearm (radius, *R*, and ulna, *U*) (*4*). These two bones are attached by ligaments to the wrist bones (*5*), which are in turn similarly united with the bones which in man form the palm of the hand (*6*). Attached to these are the bones which in man are known as fingers, and in the lower mammals as toes (*7*).

The comparison holds equally true for the posterior limbs (Fig. 8). The hip bone (*1*) (not shown in the figure) has a socket into which fits the rounded head of the femur (*2*), the single bone of the upper part of the leg. This articulates at the knee (*3*) with the two bones of the fore leg (tibia, *T*, and fibula, *F*) (*4*). At the knee joint is usually developed a bone,

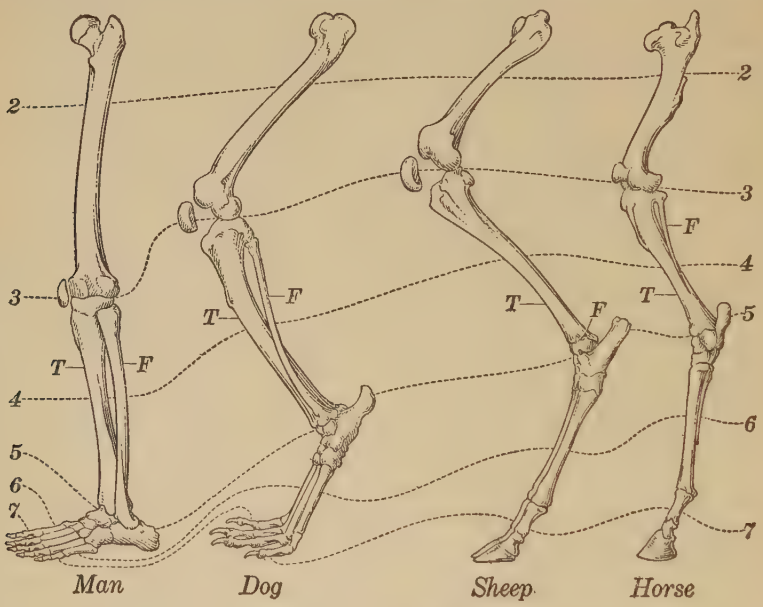


Fig. 8. A comparison of the posterior limbs of mammals
F, fibula; *T*, tibia (shin bone)

the kneecap, to protect this exposed joint. The bones of the fore leg are joined to the bones of the ankle (*5*). The most conspicuous bone of the ankle is the backward-projecting heel bone. Below the ankle bones are those of the flat of the foot (*6*), and attached to these are the toes (*7*).

The primitive, normal number of toes in both fore and hind limbs is five, but this is reduced in those animals which walk upon their toes instead of upon the flat of the foot. In the same animals there is a reduction in size of the ulna in

the fore limb and of the fibula in the hind limb, but even in the horse remnants of these bones are retained, as are also vestiges (splint bones) of the second and fourth toes (shown in the figures immediately below the wrist and ankle bones).

Despite the very different functions and environments to which the arms of man, the fore legs of the cat, the paddles of the whale, and the wings of the bat are subjected, they exhibit a similarity of bone, muscle, blood vessel, and nerve structure. It is only the superficial appearance that differs; this is comparable to the superficial differences separating the Romance languages, — a later dissimilarity superposed upon an earlier similarity.

The description of the internal skeleton of mammals given above applies also to all birds, reptiles, and amphibians. In the lowest of vertebrates, the fish, the similarity is less close. These show the common plan in having a backbone, skull, ribs, and two pairs of limbs, — the pectoral and pelvic fins. The limbs are similarly attached to the backbone, but except in the more ancient types the limb bones do not correspond at all closely to those of the other vertebrates.

2. *Muscles and nerves.* Just as corresponding bones are similar among the various classes of vertebrates, so likewise are the majority of muscles which move these bones and the nerves which govern the muscles. More than four hundred of the muscles in the cat's body occur also in all other higher mammals, including man, in the same general location and with similar function and nerve supply.

3. *Central nervous system.* The brains of all vertebrates, from fish to man, have the same general divisions (Fig. 9). These are, from front to back, the olfactory lobe, governing the sense of smell; the cerebrum, or thought center; the optic lobe, governing sight; the cerebellum, which coördinates the movements of the voluntary muscles; and the medulla, which indirectly controls breathing and furnishes many nerves to the head and neck. The medulla gradually contracts into the spinal cord, which continues backward within the backbone.

4. *Vestigial organs in the adult animal.* In many animals there are vestiges of organs which may be interpreted by a comparison with other animals. In the leg of the horse occur two splintlike bones which are attached at the sides of the bone below the hock. These are vestiges of the two side toes which the ancestral three-toed horse possessed. In man are found remnants of muscles for moving the ears and the scalp. In most adults these muscles are useless; they are more functional in children than in adults, and fully functional in the groups of mammals below man.

The modern whale has no hind limbs, though there usually occur vestiges of the hip bones and upper leg bones; but R. C. Andrews reports that in a Humpback whale of average adult size, caught in 1919 off the west coast of Vancouver Island, British Columbia, a pair of hind legs projected from the body to a length of over four feet. These legs were symmetrical and were in the exact position in which the hind-limb rudiments occur in embryonic whales. The whale had partly bony and partly cartilaginous pelvic bones, femur, tibia, tarsus, and metatarsus. This is a case of a partial reversion of vestigial organs to their ancestral useful condition.

5. *Chemical test of blood relationship.* Not only does a comparative study of the hard and soft parts of the vertebrates indicate a fundamental unity of structure which is closest between man and the other mammals, and more and more distant between man and reptile, amphibian, and fish, but the blood likewise shows a similar relationship.

Ordinary chemical analyses have so far been unable to determine any differences in the blood composition of various animals. There are several other methods of doing this, however, one of which, the precipitin test, has been used by Dr. George Nuttall and his associates in making sixteen thousand tests upon many different animals.[1] This method of distinguishing the blood of different animals has long been used in criminal cases when it has been necessary to determine

[1] G. H. F. Nuttall, Blood Immunity and Blood Relationship.

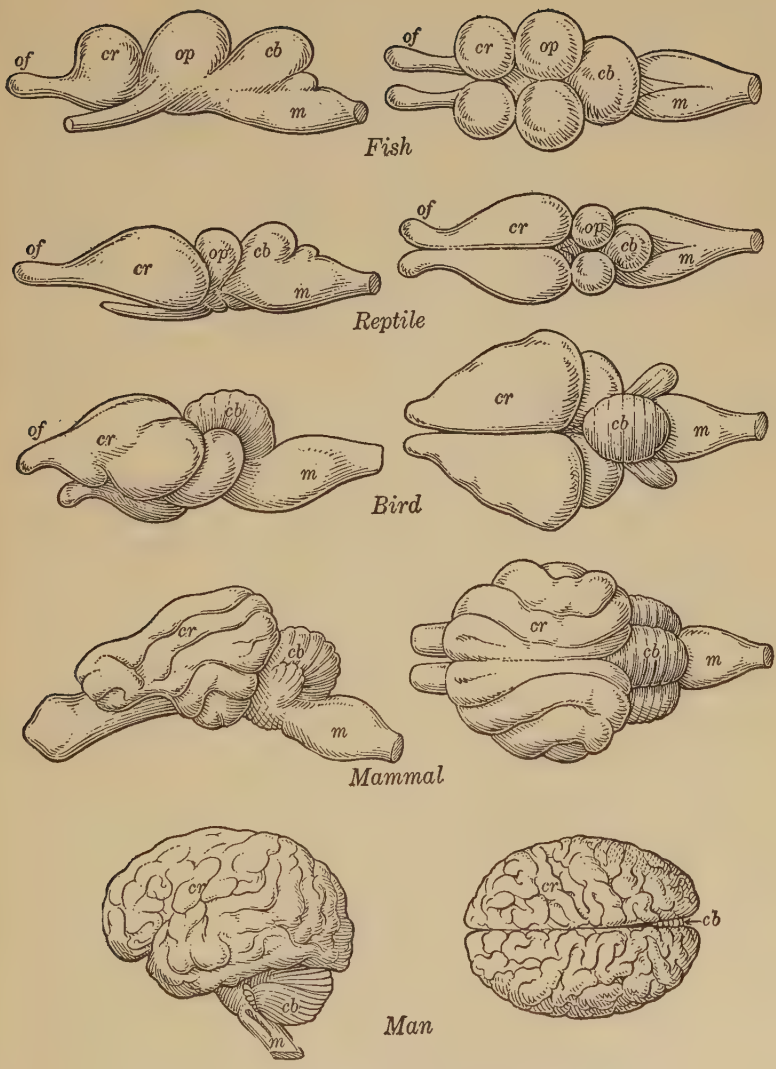


Fig. 9. A comparison of the brains of vertebrates

Man's relationship to other vertebrates is shown in the basic similarity of their brains. *cb*, cerebellum; *cr*, cerebrum; *m*, medulla; *of*, olfactory lobe; *op*, optic lobe

whether blood was human blood. The process consists in permitting some freshly drawn human blood to clot, then injecting some of the unclotted fluid (serum) into the veins of a rabbit. This causes the development of an antibody in the rabbit's blood to neutralize the foreign substance. After this the rabbit is killed, its blood is allowed to clot, and the serum (now called anti-human serum) is preserved. When a few drops of this anti-human serum is introduced into the serum from human blood, a white precipitate is formed and thrown down, but no precipitate is formed when it is introduced into chicken blood. Anti-horse, anti-pig, anti-camel, and anti-fowl sera have been similarly prepared by injecting fresh serum from a horse, pig, camel, or fowl into a rabbit.

It was found that while the largest precipitate and the one most quickly formed is obtained from the same specific blood as that which was injected into the rabbit, the blood of closely allied species gives a weaker and slower precipitation. With anti-human serum the maximum amount of precipitate is with man of any race, then, successively, with the anthropoid apes (family Simiidæ), the Old World monkeys (Cercopithecidæ), the New World monkeys (Cebidæ), and, to the smallest degree, the New World marmosets (Hapalidæ). Anti-whale serum gives slight reactions also with the blood of pigs and ruminants, while anti-lizard serum gives some precipitation in blood from snakes. If very strong solutions are used, a relationship between all the mammals is shown. The same is true of the birds.

The results of such blood tests parallel in a remarkable degree the relationship indicated by the comparative anatomy of the hard and soft parts.

6. *Crystal test of blood relationship.* When crystals are formed in the solid coloring matter (oxyhemoglobin) of the red corpuscles present in arterial blood, they are found to have specific differences in angle and habit. From these crystals it is usually possible to recognize even the species of animal.

The method usually employed is to keep the blood from coagulating by adding oxalate to the blood when collected. Later it is centrifugalized to remove extraneous matter and get a clear solution. This is then placed on slides under covers sealed with Canada balsam and allowed to crystallize. When the resultant crystals are measured so as to determine the angles and the habit of growth, the results corroborate the relationship of animals determined by comparative anatomy and paleontology. Representatives of the Primate Order (man, monkeys) develop crystals which resemble each other much more than those from any other order. In the cat family (Felidæ), including the lion, leopard, Bengal tiger, Canada lynx, puma, jaguar, and domestic cat, the crystals form a very similar group distinct from any other, though each species has some slight difference by which it may be distinguished. In the family Canidæ, including dogs, wolves, and foxes, the crystals closely resemble each other, forming a family group distinct from other family groups but varying within itself. It is seen that different strains of the domesticated dog vary among themselves, some approaching the wolf, others the jackal, etc., giving evidence that they are of different origins. Similar specific and family characteristics are shown among the crystals obtained from the blood of birds.

It is thus seen that this crystal test not only supplies further testimony of the minute chemical differences of the blood of each species but shows that these specific differences are superimposed upon a similarity which is as broad as the family; also, that these indicate the relationships which are shown independently by paleontology and comparative anatomy.

Summary. Each individual mammal, from the burrowing mole to the flying bat, from the water-dwelling seal to the land-dwelling horse, from the lowly opossum to highest man, is built upon the same plan. The bones of each are similar in number (except where a few have been lost), in position, in the muscles which move them, and in the nerves and blood

vessels which supply these muscles. Since mammals possess all these basic features in common, it is concluded, as from a similar line of evidence in the Romance languages, that all are descended from the same ancestors.

More distantly, though not the less clearly, similar lines of evidence suggest the descent of all mammals, birds, reptiles, amphibians, and fish from common, still more remote, ancestors. The evidence from comparative anatomy clearly shows that each member of any class of the vertebrates is built upon exactly the same plan as every other member of the same class, — that representatives of different classes have become changed only in the more superficial characters and in response to differing environments, just as similar changes took place in the evolution of the differences in the Romance languages. This common ancestry is likewise suggested by the blood in both its chemistry and its crystal growths.

Arthropods. The unity of structural plan seen in a comparative study of the anatomy and blood of the vertebrates is exhibited also in the study of any phylum of the invertebrates. Each member of the phylum Arthropoda (including the crayfish, crab, lobster, centipede, spider, and insect) possesses an external skeleton of chitin completely incasing it, and hence growth can take place only by a series of molts. To the inside of this skeleton the muscles are attached. The nervous system consists of a brain in the dorsal part of the head, connected with a ventral nerve running the length of the body. Under the greatly different environments of salt and fresh water, land and air, arthropods possess this unity of structure. The work of Nuttall's associates shows here also a blood relationship. Anti-crab serum gives a precipitate in the various representatives of the highest Crustacea, the decapods (shrimp, lobster, crayfish, crab), and anti-Limulus serum shows a blood relationship between the horseshoe crab and the spiders.

Echinoderms. The phylum Echinodermata consists of seven classes, three attached by rootlike processes to the earth,

four freely moving. Under the very diverse conditions of life implied in this division all retain a fivefold division of body, seen outwardly in the five ambulacra, bearing, according to superficial function, tube feet (in starfish), tube feet and respiratory hairs (sea urchins), or food-collecting hairs (crinoids). Internally they all possess a water-vascular system and a fivefold division of the nervous system.

Relation between different organisms. The grouping of organisms according to these data naturally takes the form of a tree. This unity of structural ground plan by itself indicates the existence of blood relationship, and the chemical and crystal tests show this to be a fact. When animals are grouped according to this relationship, it is seen that they assume the form of a tree in which a small branch represents a family, a larger branch a phylum. The trunk is seen to be simpler and more generalized than any branch. Such an arrangement of organisms, dependent primarily upon genetic relationship, is called a natural classification.

TOPICAL REVIEW

Romance languages.
Vertebrates:
1. Bones;
2. Muscles and nerves;
3. Central nervous system;
4. Vestigial organs in the adult animal;
5. Chemical test of blood relationship;
6. Crystal test of blood relationship;
Summary.

Arthropods.
Echinoderms.
Relation between different organisms.

CHAPTER VIII

EVIDENCE OF EVOLUTION FROM ONTOGENY

In addition to the evidence of evolution that is given by paleontology and by comparative anatomy, much corroborative testimony is furnished in the development of a plant or an animal. It is not alone in the embryology of each organism that evidence of ancestral history is to be found; it can be discerned throughout the complete series of growth stages, from fertilization to the adult, — in other words, throughout the ontogeny of each plant and animal.

Recapitulation. Each organism during its growth exhibits peculiarities which seem to find their best explanation in the hypothesis that it passes rapidly through the basic changes which were slowly evolved by its succession of ancestors during their development from one-celled forms. According to this interpretation the development of the individual plant or animal from fertilization to adulthood is an abbreviated repetition of the basic changes evolved by its ancestors during the millions of years of life upon earth; as Huxley has said, each animal, in its development, climbs its own ancestral tree. This race history of a plant or animal type is known as its phylogeny. Hence the hypothesis of recapitulation may be briefly stated thus: ontogeny repeats phylogeny. The repetition is, however, of the basic features only. The embryonic bird, for example, does not have hardened scales as did its reptilian ancestors, but the bases of the scales are present with the same arrangement. In this case, however, growth to adulthood changes them to feathers, except upon the lower parts of the legs, where reptile-like scales are retained.

Examples of recapitulation. *Flounder.* The adult flounder differs from normal fish in lying on one side both in swimming

and in resting, and both its eyes are borne on the upper surface. When it is hatched, however, it swims vertically and bears an eye on each side of its head. During its growth it comes to rest more and more on one side, and the eye of the lower side grows upward and around the head until it appears upon the upper side. The normal condition of the young is held to indicate that the ancestors of the flounder were normal both in eyes and in mode of swimming, and that the young flounder recapitulates this normal fish state of its ancestors.

Tunicate. A common tenant of our coasts is a small, frequently greenish, vaselike organism possessing two openings at the top and fastened firmly by its base to seaweed or rock. It looks much like a plant, and this resemblance is emphasized by the great amount of woody fiber in the structure of its body walls. Yet this little ascidian, or tunicate, breathes and eats by drawing a current of water in through one opening of the body and out at the other, and from time to time it scatters its eggs. It is to be noted that these eggs, instead of hatching directly into forms like their parents, develop into tadpole-like creatures with sense organs, gills, and a notochord (a foreshadowing of a backbone), giving all the promise of becoming a frog or a higher vertebrate. But after a few hours of the freedom of swimming about, the spasm of degeneracy seizes it, thrusts it upon a rock or fucus frond, obliterates its sense organs, its notochord, — all badges of superiority. This roundabout way of becoming kin in appearance to a lowly plant, this development from simplicity to complexity and back again to simplicity of structure, can be explained only on the hypothesis that in its ontogeny this creature is repeating its phylogeny.

Spirifer centronatus. Any animal which has an external shell, like the clam, snail, or brachiopod, carries on this shell a record of any changes that take place in shape and ornamentation. These changes, recorded from the beak, or tip, to the front, or large end, of the shell, were added successively throughout life. Hence, in preserving its successive growth

stages, a shelled animal furnishes a record of the succession of adult forms in its ancestry. An example of such recapitulation is seen in two species of brachiopods found in the early Mississippian rocks of southwestern Alberta (Fig. 10). Here occur 1000 feet of sediment of this age, — largely limestone.

In the lower 200 feet *Spirifer albapinensis* is found in abundance, with no representative of the related species *Spirifer centronatus*, which appears rarely just above this level, but

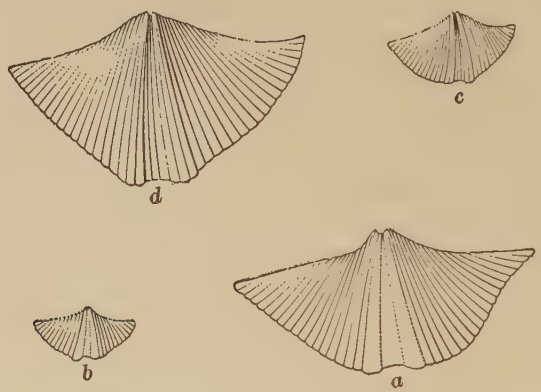


Fig. 10. Recapitulation in the brachiopod *Spirifer centronatus*

a, *Spirifer albapinensis*, the ancestor of *Spirifer centronatus* (*d*); *b*, very young stage of *S. centronatus*, when it has all the characters of *S. albapinensis*; *c*, a later stage approaching the adult of *S. centronatus*

becomes abundant after the deposition of 300 additional feet of limestone; it continues abundant and is accompanied by no specimens of the former species up to the top of this series of beds. Judging from their appearance in time, as indicated by their relative positions in sediments in which they were entombed, and from the shape and ornamentation of the shells, *S. centronatus* developed from *S. albapinensis*.

Considering only the pedicle valve, *S. albapinensis* has the median sinus narrow and bounded on each side by a conspicuous and broad plication. The other plications are low and narrow. The breadth of the shell much exceeds the length.

These are also the characters of the young shell of *S. centronatus*. After this youthful stage, however, the shell of *S. centronatus* increases more in length than in breadth, and the plications bounding the median sinus become smaller by dividing two or three times and sending the smaller divisions into the sinus, which thus has added to it several plications. The other plications in the shell do not change from those of *S. albapinensis* in form or in number. The best explanation of these peculiarities in the development of *S. centronatus* is that the young repeat (that is, recapitulate) in their growth the adult shape of their ancestor, *S. albapinensis*.

Vestigial organs in the embryo. In the development of plants and animals many organs occur which disappear before adulthood is reached. Some of these temporary structures have clearly developed in response to the needs of embryonic life. The majority, however, can be reasonably explained only on the supposition that they are a repetition of organs which were of use to adult ancestors, and are thus vestigial organs. A full row of teeth is developed in the embryo of the whalebone whales. These are never of any use, since they are lost either before or soon after birth. Similarly, in the cud-chewing mammals incisors are present in the upper jaw of the embryo but not of the adult.

In Amblyopsis, a blindfish in the waters of such caves as the Mammoth Cave of Kentucky, the embryo develops all the foundations of a normal eye. In the further growth of the young fish the eye and all its structures deteriorate to a state of perfect blindness. This roundabout way to blindness, through the development of an eye and its subsequent destruction, suggests that the ancestors of Amblyopsis had and used normal eyes, — that the blindfish is descended from a normal fish.

Interesting vestigial structures are seen in the teeth, wing-claws, and numerous tail vertebræ of modern birds. The young of some parrots develop teeth which are resorbed before they break through the gums. The wings of the present-

day birds have usually no claws, but three digits bear claws in the ostrich, and one and sometimes two bear claws in the rhea, cassowary, emu, kiwi (apteryx), the crested screamer, and, very rarely, the goose and common fowl. In the nestling of hoactzin two claws are present which become resorbed by the time the bird is fully grown. During early-growth stages (that is, while they are still within the egg) all birds possess a much longer tail than they have later. In the adult bird the tail ends in a small bony plate (the pygostyle) which represents the fusion, with great shortening, of from four to six vertebræ; besides the pygostyle there are usually six free vertebræ in the tail.

The occurrence of teeth, claws on the digits of the fore limbs, and a long vertebrated tail in the ontogeny of birds living today can be best explained on the supposition that the young still repeat in their growth some characters used by their ancestors but no longer necessary. Evidence of such early use is seen in the succession of fossil birds. In the Cretaceous, the period immediately preceding the present (Cenozoic) era, the birds had long, sharp, functional teeth, except in the front of the jaw; one (Hesperornis) had twelve mostly free vertebræ composing the tail; claws are not definitely known. Still earlier, in the Jurassic, the birds had teeth from the back to the front of the jaws, three claws on the digits of the fore limbs, and twenty vertebræ in the tail.

Thus, combining the facts revealed by paleontology and ontogeny, we see the birds gradually changing as the ages passed. The long vertebrated tail gradually shortened, the claws almost entirely disappeared from the digits of the fore limbs, and the teeth became obliterated. Yet we see that living birds in their growth still develop these characters, — numerous tail vertebræ, teeth, and claws, but gradually as growth proceeds through embryonic life to adulthood they are usually resorbed. The disappearance of teeth in the front of the jaws of Cretaceous birds seems to be correlated with the development of a horny beak, which during the Cenozoic took over entirely the function of teeth.

Life history of the oyster. To illustrate that an individual organism in its growth passes through stages that suggest various types in its ancestral record, the life history of the common edible oyster may be described. The earliest stage is the fertilized, single-celled egg (one-celled stage), about $\frac{1}{400}$ of an inch in diameter. This subdivides rapidly into a round mass of many cells (early many-celled stage). Later one side of this mass sinks inward, forming a sac, the gastrula. There follows a rapid development into a form, the trochosphere stage, which is characterized by a circle of hairlike cilia by means of which the animal can move slowly through the water. Later the phylembryonic stage develops, in which characters appear which show that the embryo belongs to the class *Pelecypoda*. During this stage a shell gland is developed, which, dividing along its median line, secretes two valves of hornlike conchiolin. This earliest shell consists of flat, equal valves with a straight hinge line furnished with minute interlocking teeth. The valves are closed by a single muscle, — the anterior adductor, as is seen later by the development of the second muscle. The succeeding stage is called the Nucula stage, because its form and organs characterize the still living but very primitive pelecypod-genus Nucula. At this time the shell develops high umbos (beaks) which are directed posteriorly. It now possesses a curved hinge line with many teeth and deeply concave and nearly equal valves closed by two muscles. It has two pairs of simple gills. At the close of this stage, about the sixth day of its life, it falls to the bottom of the water and attaches itself to some clean solid surface by the edge of its mantle. Later this attachment is made firm by a secretion first of conchiolin and later of lime. The lower (left) valve becomes more concave, while the upper (right) valve flattens. During this time the anterior muscle disappears, the gill filaments increase in number, a cartilage pit develops at the right of the umbo, and the teeth disappear. The embryo has become the typical oyster, except in external shape and in size.

This succession in the embryological development corresponds to the appearance of various groups in geologic time. Protozoa are known from the Pre-Cambrian, pelecypods from the Cambrian, Nucula from the Ordovician, and the oyster from the Carboniferous.

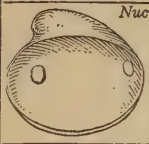
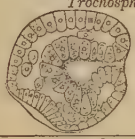
Thus during its growth from the egg to the adult state the oyster passes through stages corresponding to groups listed in the table on page 73.

Distortion of the record. Upon the hypothesis that all living forms today have gradually evolved from the same primal ancestors it is to be expected that throughout these many millions of years the record would become to a greater or less degree distorted. There would be the addition of characters used during the larval life, since this would also change, as well as the adult. The usual cause of such distortion, however, is the elimination of characters because of the necessary acceleration in development as more and more growth stages are added to an evolving group. The oyster repeats in six days of its ontogeny what it took many millions of years for its ancestors to evolve. The important goal in the life of each individual plant and animal is the attainment of adulthood. Hence it is to be expected that many ancestral characters are omitted from the ontogeny. The first and fifth toes of the horse fail to be repeated in its ontogeny, though the second and fourth occur when the embryo has a length of about four inches. In the adult horse of today the third toe only is functional, but the paleontological records indicate that all five were utilized in the earliest Tertiary. Thus in this case the outermost pair of toes, the first that deteriorates in the adult as shown by fossil remains, is the first to disappear entirely in the ontogeny; yet even the succeeding pair, the second and fourth digits, have become crowded back to the very young, four-inch embryo.

Summary. The force which tends to make offspring resemble their ancestors, near and remote, is called heredity. When heredity is indicated in brief and transient stages of the

Table X. Ontogeny repeats Phylogeny in the Oyster

During its growth from the egg to a fully grown adult, that is, during its ontogeny, the oyster passes through the stages indicated below. These stages characterize the groups of animals indicated, suggesting the phylogeny (the ancestral history) of the oyster. In the last column is noted the age of earliest fossil appearance. The middle column summarizes the evolution of the oyster from the protozoan, while the first column shows how the oyster in its growth today passes successively through these steps

Ontogenetic Stages	Phylogenetic Groups	Geologic Ages
Oyster	*Specialized pelecypod*	*Carboniferous*
 *Nucula*	*Primitive pelecypod*	*Ordovician*
Phylembryo	*Very primitive pelecypod*	*Cambrian*
 *Trochosphere*	*Wormlike*	*Proterozoic*
Gastrula	*Cœlenterate*	*Proterozoic*
Early many-celled	*Primitive sponge*	*Proterozoic*
One-celled	*Protozoa*	*Archeozoic (Archean)?*

offspring's developmental history, it is called recapitulation. It would seem to be a fundamental law of growth that an individual thus passes in review through the heritage which he has received from even his remotest ancestors. Each organism may be considered as passing by express train over the road which his ancestors slowly built. There are many difficulties in the reading of the past history thus recorded. There is a tendency to accelerate the development, to abbreviate the more ancient history, and thus to drop out many of the stages. We may compare the growth of an organism to the flow of a drop of water down a river bed. It must in general follow the road which those preceding it have marked out, though it may aid in shortening the meanders and thus hasten its passage to the sea. This shortening of meanders, or acceleration of passage, changes the river bed to some extent, but the very broad curves in the direction of flow remain. So in the growth of an organism from the egg to adulthood, organs unnecessary to the adult, like meanders in the course of a stream, tend to disappear. This tendency to shorten, or acceleration in development, is responsible for much of the difficulty in the interpretation of embryology. Even though many characters present in the ancestral adults must thus, on this hypothesis, be lacking in ontogeny, yet those which remain (the vestigial organs) are of the greatest aid in classifying plants and animals, and their presence can be accounted for on no other hypothesis. Thus can be explained the tadpole-like form of the young tunicate with its notochord, the free-swimming Cypris-stage of the young barnacle with its bivalve shell, teeth in birds and in whalebone whales, side toes in the horse, and the hairy covering (lanugo) in man. The only logical explanation of such vestigial organs, which are developed during the growth of the individual only to be again partially or wholly destroyed before adulthood is attained, is that they subserved some distinct use to early forbears. Since present-day individuals do not use these organs, the logical conclusion is that they have descended from ancestors that did use them.

TOPICAL REVIEW

Ontogeny defined.
Recapitulation (Ontogeny repeats phylogeny).
Examples of recapitulation:
  Flounder;
  Tunicate;
  Spirifer centronatus.
Vestigial organs in the embryo.
Life history of the oyster.
Distortion of the record.
Summary.

CHAPTER IX

EVIDENCE OF EVOLUTION FROM GEOGRAPHIC DISTRIBUTION

Usually the animals and plants of neighboring regions are most similar, and those of regions most remote from each other are most unlike. There are, however, many instances of strikingly similar faunas and floras in widely separated regions, while, on the other hand, it often happens that organisms of as strikingly diverse character are found separated by only a narrow area. The fact of the present geographical distribution of organisms — the fact that some forms are in a certain locality and others are not there — needs some explanation besides that of the influence of the present environment. Evolution furnishes such an explanation. According to this hypothesis, animals and plants are either in the places where they have evolved from preëxisting species or in those to which they or their ancestors have migrated. The former alternative explains the usual similarity of neighboring forms and the dissimilarity of those remote; the latter alternative explains the similarity of some faunas and floras now widely separated and the dissimilarity of some now near to each other.

The fact of migration and how it is brought about. The migration of animals and plants today is an observed fact. The little marine snail, *Littorina littorea*, was observed in the Gulf of St. Lawrence in 1850, on the coast of Maine in 1870, at Salem, Massachusetts, in 1872, at New Haven, Connecticut, in 1890, and in Delaware Bay in 1891. In each place, within a few years after its first appearance, it had become the most abundant snail on the coast. That it was not present in these regions in earlier times is shown by the fact

that no specimens of it occur among the numerous fossils of Pleistocene and later times found here.

Among plants and water-dwelling invertebrate animals the most important of the causes bringing about migration is their planktonic life during a portion of their early stages of existence. At that time they are mere passengers of the waves and currents, and may be swept into regions hitherto unpeopled by their kind. Adult insects and vertebrates can travel considerable distances through air and upon the earth. Vertebrates migrate in their search for food and in their retreat from enemies. The range of such wanderings may be enlarged, especially in the case of the higher mammals and birds, by curiosity to find what lies beyond the next ridge or in the more distant trees. Involuntary migration is effected when organisms are transported on driftwood. Such instances have been frequently noted. The eruption of the volcanic island of Krakatao in 1883 destroyed every living organism on it by burying all deeply under volcanic débris; yet, by transportation on natural rafts, and, as plankton, by the agency of waves, life again found footing, and twenty-three years later the island possessed a flourishing growth of spiders, insects, and lizards, among animals, and of many plants, including the coconut palm. In this case restocking took place quickly, since Java lies only twelve miles to the southeast and Sumatra to the north.

Evidence of change in land connections. That North America and South America were disconnected during parts of the Tertiary period is shown by the presence of sediment with marine fossils across the Isthmus of Panama. Similar evidence shows that during the early Tertiary the Mediterranean Sea extended unbroken across Asia Minor to the Indian Ocean. Sediment containing marine fossils furnishes the principal testimony that present land areas were at one time covered by ocean waters. Similar evidence as to the present separation of lands that were once connected is wanting, since the connection is now beneath the sea, and the absence of marine

sediment cannot be noted. Lands of recent submergence are, however, covered only to a moderate depth in contrast to the normal profound ocean depths. Such shoal waters are one of the indications of the recent connection of Alaska and Siberia, and of Great Britain with the continent of Europe.

Closely related species in neighboring regions. Since evolution implies the slow change of one species into another species, and the still slower change of one genus into another genus, we should expect (from this viewpoint) that the organic types living in any geographical area would be found to resemble or differ from organic types living elsewhere according as these areas are connected or disconnected. In each of the climatically similar but widely separated land masses of South America, Africa, and Australia the vast majority of the species of plants and animals are distinct, while the climatically similar and proximal land masses of Eurasia and North America have very many species in common.

What is true of such large land masses is just as true of smaller ones. The Galápagos Islands, six hundred miles west of Ecuador and surrounded by abyssal ocean waters, are characterized mostly by distinct species of plants and animals, and these organisms most nearly resemble South American forms. The Cape Verde Islands, four hundred miles west of Senegal and surrounded by abyssal ocean waters, possess very many distinct species, and these most nearly resemble African forms. While these two groups of islands are similar in size, height, soil, and climate, the life upon them has almost nothing in common. The life of each is most like that of the nearest land mass. It is natural that the islands should receive colonists from the nearest lands through migration by means of natural rafts. These colonists have since become modified into distinct species, though they still betray their original birthplace.

On the other hand, the British Isles, which are separated from France by only a few miles, — a separation which took place in very recent geologic times, — have few distinct species

(about one in a hundred). The rest are identical with those on the mainland of Europe.

Closely related species in widely separated regions. Where closely related species live today in widely separated regions, it is found from fossils that they also occupied the intermediate territory during the time immediately preceding the present. All the few living species of magnolia, sassafras, sweet-gum (Liquidambar), witch-hazel (Hamamelis), spice-bush (Benzoin), tulip tree (Liriodendron), and many others are today confined to the southern and eastern portions of North America and Asia. But all these genera, at times represented by the same species, were abundant in Europe during the Pliocene or even in the early Pleistocene. They died out in Europe because, during the Pleistocene glacial period, the Mediterranean Sea prevented such southward migration into warmer lands as took place on the other northern continents.

The camel family comprises the true camels, native to Asia, and the llamas etc. of South America. This family, during the greater part of its history, was confined to North America. By the Pliocene time representatives had migrated to India and south to Argentina. During the Pleistocene they died off in North America, but continued living in Asia and South America.

Present geographical distribution of terrestrial life. The lands today are divided into five life regions. (1) The Holarctic comprises North America (with the exception of the lowlands of Mexico and northern Central America), Europe, northern Africa, and Asia south to Arabia, the southern slopes of the Himalaya Mountains, and the mountains on the northern border of the Yangtse valley. (2) The Neotropical includes the remainder of North America, the West Indies, and South America. (3) The Ethiopian consists of Africa, south of the Sahara; also Arabia and neighboring islands. (4) The Oriental embraces the remaining southern peninsula of Asia east of the Persian Gulf, and also the East Indies lying to the west and north of New Guinea. (5) The Australian consists of

Australia and neighboring islands, New Guinea, New Zealand, and the other islands of the southwestern Pacific.

Of these five regions the Holarctic has the most species in common, and until recently they have had no barriers separating them. Until the Miocene, North America and Europe were united by land across the North Atlantic, and Alaska and Asia were similarly united until the Holocene. These regions are so similar in plants and animals that they are included in a single life realm. The separation has been of sufficiently long duration, however, to give to North America (Nearctic) such distinct species as the skunk, raccoon, pronghorn antelope, rattlesnake, blue jay, prairie dog, turkey, tobacco, etc., while confined to the Eurasian region (Palearctic) are such forms as hedgehogs, wild pigs, twenty species of sheep and goats, and twenty-seven species of rodents.

That these differences in plants and animals are due to distance and to the strength of separating barriers is seen by the fact that while western and eastern North America each possesses many species distinct from the other, and while the same is true of Europe and eastern Asia, North America as a whole and Eurasia are still more diverse as to species, while the species of the Holarctic region (North American and Eurasian) are almost entirely distinct from those of the corresponding latitudes in the southern hemisphere.

In the Neotropical region (South America etc.) there is an absence of all forms of sheep, oxen, antelopes, true flycatchers, and starlings. There is here a preponderance of such archaic mammals as edentates, marsupials, and rodents. Here are found agouties, sloths, armadillos, anteaters, peccaries, llamas, alpacas, twenty species of opossums, four hundred species of humming birds, and very many toucans and macaws. In reptiles, amphibians, fresh-water fishes, and insects this region is equally peculiar. The life peculiarities of the Neotropical realm are almost as marked as those of Australia, but it contains a greater variety of forms, for in the late Cenozoic it had a broader and less mountainous connection with North

America than now, while the Australian region has been continuously separated from Asia since the beginning of this era.

The Ethiopian region (Africa etc.) is characterized by such animals as the gorilla, the chimpanzee, baboons, many lemurs, the zebra, the hippopotamus, the African elephant, the giraffe, over seventy peculiar species of antelopes, four genera of guinea fowls, and the true ostriches.

In the Oriental region (India etc.) are found the orang-utan, gibbon, tiger, Indian elephant, five species of rhinoceros, peacocks, argus pheasants, and the jungle fowl (*Gallus bankiva*), — the ancestor of our domestic cocks and hens.

In the Australian region there is an almost total absence of all animals which characterize the rest of the world. There are no native insectivores, carnivores, or ungulates. Aside from a few bats, mice, and rats its mammals are exclusively monotremes and marsupials. The place of other mammals in the economy of nature is taken by a great radiation of the marsupials (a well-known representative of this order in North America is the opossum). In this region are found such characteristic forms as the kangaroos, wallabies, phalangers, and Tasmanian wolf among the marsupials, while among the birds occur many species of parrots and pigeons, the mound-builders, emus, and cassowaries.

TOPICAL REVIEW

The fact of migration and how it is brought about.
Evidence of change in land connections.
Closely related species in neighboring regions.
Closely related species in widely separated regions.
Present geographical distribution of terrestrial life.

IV

CAUSAL FACTORS OF EVOLUTION

It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with reproduction; Inheritance, which is almost implied by reproduction; Variability from the indirect and direct action of the conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less Improved forms. . . . There is grandeur in this view of life with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, while this planet has gone circling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been and are being evolved. — CHARLES DARWIN

INTRODUCTION

Variation. *The most fundamental factor in evolution is variation. Change is essential to any sequence of cause and effect, and is the most notable characteristic of any series of living forms. No two kittens in a litter are alike; they vary in form, in color, in length and thickness of fur. No two leaves upon a tree are exactly similar in size, shape, nerves, and arrangement of cells. No two plants developed from the seed of a single flower head are exactly alike. This fact is so common that we take it for granted. If two children in the same family are so similar as to be distinguished with difficulty, it is considered noteworthy; and yet the really remarkable thing is that offspring of the same parents differ at all, since apparently they are products of the same heredity and are subject to the same environment.*

Of these variations it is supposed that some arise from changes in the germ cells and may thus be passed on to offspring. Others are due to modifications of the ordinary body cells and are not immediately, possibly not at all, heritable. It is only those modifications which may be handed on to offspring that effect the evolution of a species. The majority of variations seen about us are probably somatic rather than germinal. They are modifications of the organism due to environment rather than changes in the germ plasm. They occur at all stages from the egg to adulthood. An unfavorable environment during growth, such as too little of the right kind of good food, or abnormal temperature, or impure air, will produce dwarfed and abnormal individuals. Plants become dwarfed in poor soil; men become goitrous when their food contains insufficient iodine.

Heredity. *Unless changes are passed on to offspring there can be no evolution. The factor which brings about this transmission of physical and psychical changes of one generation to the next is heredity. This is the conservative, the preservative, factor in evolution. It is this factor which causes the acorn to develop into an oak instead of into an eagle. There is no reason why one speck of protoplasm should develop into an oak and another speck into an eagle except for something that each bears within itself, — its memory of the road that its parents have traveled. Heredity is the stabilizing element in evolution.*

Selection. *Under ordinary conditions, when the varying organisms are not segregated, interbreeding with the old stock occurs, and the old characters continue. The variations which take place in so very many directions tend to cancel one another, so that any one of them has little chance for perpetuation unless it is segregated. A prevention of interbreeding may result from such internal factors as a variation in the direction of a physiological inability to interbreed, or from such external factors as geographic separation, or differences in moisture and in soil. Under such conditions of segregation, variations may survive and in time produce an organism that differs greatly from its remoter parent stock.*

Given the tendency of plants and animals to vary, and the transmission of these variations through heredity to offspring, the result will be that those individuals survive which are best fitted to the conditions under which they live. In other words, natural selection, the discriminative action of the environment, tends to preserve certain variations in species and to eliminate others.

Evolution is thus seen as a natural process of continuous change in animals and plants, — the result of internally produced variations acted upon by external conditions.

CHAPTER X

INTERNAL FACTORS OF EVOLUTION

Internally produced variations are due to changes in the germ cell. They may originate from varied combinations of germ cells through crossing and may be passed on to descendants if the organism possessing them is geographically isolated; or they may arise as heritable differences between parents and offspring — in this case segregation is internal. The larger of such inherited differences are known as mutations and sports. That most species are the result of minute continuous variations, however, is indicated by the study of series of fossils from successive strata.

MENDELISM

Statement. The law that governs the combination of germ cells was first formulated by Gregor Mendel, a monk in a monastery at Brünn, Austria, of which he later became abbot. In the monastery gardens Mendel experimented with the crossing of different kinds of peas which had distinctive characters. He then counted the offspring of successive generations, noting in each case the number possessing each distinctive character.

Mendel crossed smooth peas with wrinkled peas. In this experiment, which has been repeated frequently by others, care is taken to remove all the pollen-bearing anthers from the flowers of one variety, as, for instance, the smooth peas, to prevent self-fertilization. Later, pollen from flowers raised from wrinkled peas is shaken upon the stigmas of the smooth variety. Each flower is then covered with a small paper bag to keep insects or winds from bringing different pollen. The resultant peas in such an experiment are all smooth. The

progeny, however, of any of these smooth peas, when self-fertilized, is of two kinds, in the proportion of three smooth to one wrinkled. If the experiment is carried on to the next generation and these smooth and wrinkled peas are self-fertilized in their turn, it is found that one third of the smooth peas produce only smooth, that in the other two thirds the offspring are again in the proportion of three smooth to one

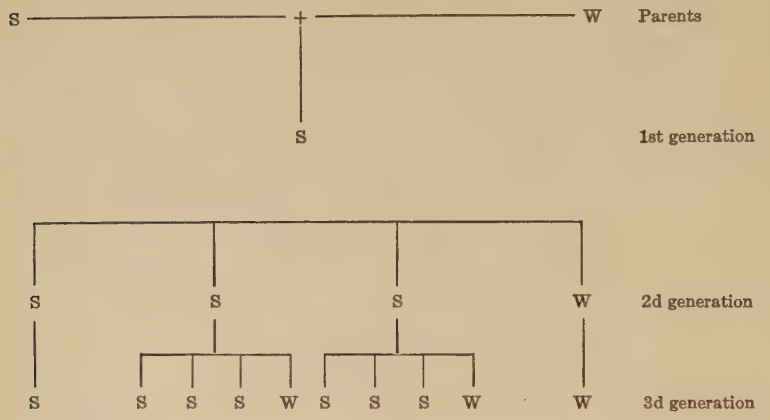


Fig. 11. Mendelian segregation in two varieties of the edible pea (*Pisum sativum*)

The smooth pea (S) was crossed with the wrinkled (W), with the resultant of all smooth peas in the first generation. These, self-fertilized, gave rise to the proportion of 3 : 1 in the second generation; and these, self-fertilized, gave rise to the proportion seen in the third generation

wrinkled, and that the wrinkled produce only wrinkled peas henceforth. This succession is summarized as shown in Fig. 11.

Interpretation. The factor that produces wrinkling is thus seen to be present in the first generation after crossing, though concealed beneath the "dominant" smoothness. (The factor that appears to the exclusion of the other is the dominant factor; the factor that lies concealed is the recessive.) The proportion of smooth and wrinkled peas that appear in the second generation is the proportion that would obtain if the two factors were incapable of union, each acting always

as a separate unit character (gene), and if, after a thorough stirring up, they were selected at random, that is, according to the laws of probabilities (Fig. 12).

Practical application. The discovery of the Mendelian law of inheritance has been of practical use in the cultivation of desired varieties of grains and fruits, cattle, and poultry. As early as 1890 the National Association of British and Irish

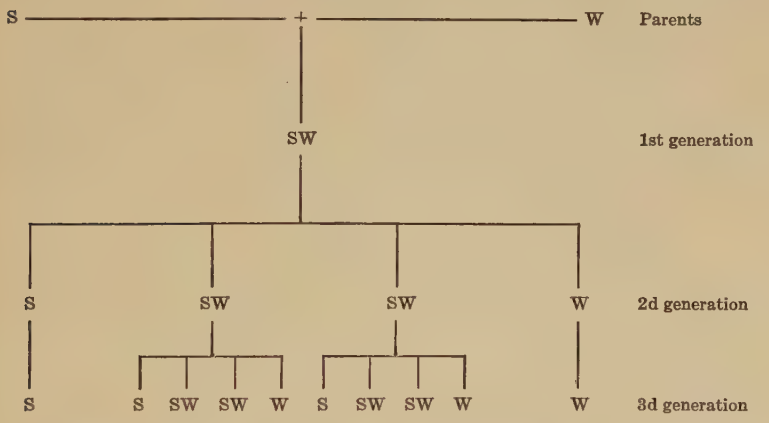


Fig. 12. Analysis of Fig. 11 as to distribution of unit characters

Observation of Fig. 11 indicates that, in the first generation after crossing, each pea must contain unit characters for both smoothness and wrinkling, for when self-fertilized they appear (in the second generation) separated in one half of the progeny (the extremes in the figure), while within each pea of the other half both unit characters are present. This is indicated in the third generation. (The hybrid peas (SW) are, of course, in outward appearance, indistinguishable from the smooth, because in them the smooth quality is dominant)

Millers called attention to the fact that the quality of wheat grown in their countries had deteriorated. It was very low in gluten, — that ingredient which gives to bread its elasticity and its ability to remain firm and yet light. Hence it could not compete with the Canadian wheat of high glutinous quality. Finally, in its difficulty, the association voted funds for experimental research and asked Professor Biffen of the Cambridge University Agricultural Department to conduct it. Professor Biffen investigated along Mendelian lines, cross-

ing varieties of wheat collected from various parts of the earth. By this means he was able to determine the various unit characters that occur in wheat. Among many others he found that a thick stem was dominant over a thin stem, and a highly glutinous grain dominant over a starchy grain. He could now make the necessary crossings to produce the variety he wished. Two of the new varieties of wheat developed (Yeoman, which combines a high yield with a high gluten content, and Little Joss, which is immune from the parasitic fungus, rust) are now among the most popular wheats in Great Britain.

Usually so many factors are involved in crossing that it is necessary to select the seed each year to keep the yield and other desirable qualities up to standard, and a recrossing at intervals is usually needed.

Blending occurs at times, especially in the first generation after crossing. Thus the crossing of red with white cattle produces only roans. These, when interbred, give rise to reds, roans, and white in the proportion of 1 : 2 : 1. From this generation the reds and whites breed true. In mankind the blending of black and white gives mulatto. That this inheritance of skin color is at least partly Mendelian, with probably two or more factors involved, is indicated by the analyses of various mulatto families. In one case, in which the father was 13 per cent black and the mother 45 per cent black, the nine children ranged from 46 per cent to 6 per cent black. The 6 per cent child was really white as far as skin color was concerned.

In some experiments the dominant unit characters appear gradually to extinguish the recessive ones, so that instead of being 3 : 1 the ratio may reach 20 : 1 or more. There also appears to be at times an increase of vigor from crossing, which may show itself in great variation and mutation, and it is upon this that many workers, as did Luther Burbank, largely depend for their selection. It is necessary to add that Mendel's law, though of the greatest importance, cannot be

considered universally applicable until more is known about unit characters.

A knowledge of this subject is of great importance not only to the breeder of plants and animals but to all those who are interested in the betterment of mankind; for it is seen that in inheritance certain characters are dominant over certain others, and that characters such as color, tooth structure, size, insanity, tendency to certain diseases, etc. may be carried and transmitted even by an adult who gives no signs of carrying the inheritance, but whose ancestors possessed it. It is also suggestive that under certain conditions of breeding the recessive characters may become permanently lost, and that dominant characters are more apt to appear in the offspring than are recessive ones.

Mendelian combinations, however, probably play an altogether secondary part in supplying materials of evolution in a state of nature.

MUTATION

It has long been known that new forms occur suddenly, without any apparent cause so far as is now known. Such newly developed, very distinct forms were called "sports" by Darwin. The Ancon breed of sheep is an example. It arose on a New Hampshire farm when there was born, in 1791, a short-legged ram from normal parents. It was a breed which was quite popular for some time because of its inability to jump fences. Mutations are such sudden heritable changes of structure which are more minute than sports.

Hugo de Vries, an eminent Dutch botanist, was the first to define mutation in this sense. He gives evidence of its frequent occurrence among plants both in a natural state and under cultivation. Such minute changes may be slight differences in size, in leaf structure, in color, etc. In his work on Lamarck's evening primrose (*Œnothera lamarckiana*) de Vries produced in his garden, in seven generations, about 50,000 plants, of which about 800 were mutations belonging to seven varieties.

Since, when the flowers of these new forms were fertilized with pollen from the same plant or the same kind of plant they gave rise to forms like themselves, they must be considered as true species. Besides these seven varieties, other forms were produced, which, for various reasons, could not be perpetuated.

De Vries, in his "Species and Varieties, their Origin by Mutation," has given evidence, from many plants, of the appearance of mutants uninfluenced by man, living in a state of purity among representatives of the parent species. Among others from Europe he cites the yellow deadly nightshade, the cut-leaved celandine, an evening primrose, an Epilobium, a campion (Lychnis), and the well-known purple beech, the last appearing as a mutant in three different places. These usually breed true from the seed, no matter where planted. The work of D. T. MacDougal in the New York Botanical Garden corroborates the conclusions reached by de Vries. In his work on the fruit fly (*Drosophila melanogaster*) T. H. Morgan has noted hundreds of mutations, though the majority are of such a character as to lead to the death of the individual possessing them. It has been suggested that rapid increase in numbers, a sign of great vigor, may be one of the causes leading to the appearance of a mutation period in a species.

Importance of mutation in evolution. As T. H. Morgan says in "Evolution and Adaptation," "If we assume that mutations have furnished the material for the process of evolution, the whole problem appears in a different light from that in which it was placed by Darwin when he assumed that the fluctuating variations are the kind which give the material for evolution." Since the mutations arise in large numbers spontaneously year after year, the danger of being obliterated through crossing with the parent form is lessened. When the new form has a different time of reaching maturity from the parent, it will be kept from crossing. A new organ may thus arise and persist, even though it is put to no immediate use, provided it is not detrimental to the organism.

While it has been shown by many workers that mutations do occur in sufficient numbers to be a distinct factor in the evolution of new forms, almost nothing is yet known as to their cause. Some authors, like E. C. Jeffrey, believe that they are the result of hybridization.

TOPICAL REVIEW

Mendelism:
- Statement;
- Interpretation;
- Practical application.

Mutation:
- Importance of mutation in evolution.

CHAPTER XI

HEREDITY

The fact of heredity. Every individual plant and animal in the world starts its life as a single cell, — a minute speck of protoplasm. Of the single cells developing into animals some will not advance beyond the comparatively simple many-celled stage of the sponge, others will develop into fish, while still others will pass on into the mammal stage. In each case the speck of protoplasm passes from the external similarity of the one-cell stage to the dissimilarity of an adult stage like its parents. It thus appears that each beginning cell contains within itself powers for developing successive mechanisms by means of which the organism is forced to travel the road which its parents traversed. In other words, each cell carries with it a sort of chemical memory of the road. Heredity is the factor in evolution which determines whether a certain speck of protoplasm shall develop into a rosebush, a clam, or an eagle.

The mechanism of heredity. What is the mechanism of heredity and where does it reside within the body? As to the first query little is known. It is probably, at least indirectly, chemical in nature, one chemical factor producing certain results in the growing body and also giving rise to another chemical agent which in turn causes further bodily changes, — a chemical chain in which one unit produces the next. The answer to the second question is more definite.

The mechanism of heredity is resident within the chromosomes of the nucleus. Each plant or animal is made up of one or more cells. A tree or the human body consists of many millions of cells. In each cell is a ball-shaped body, the nucleus, within the protoplasm of which are rod-shaped

bodies, the chromosomes, or color bodies, so called because, when the cell is stained, these absorb much of the stain (Fig. 13). When the nucleus is removed from the cell, the cell can neither grow nor divide into other cells. When, further, the chromosomes within the nucleus are disturbed, subsequent growth is defective. This indicates that the heredity mechanism resides within the chromosomes of the nucleus and is connected with their definite arrangement.

A nucleus, with its chromosomes, occurs in each cell of an organism, irrespective of the size of the plant or animal. Is the heredity mechanism, then, resident in each cell?

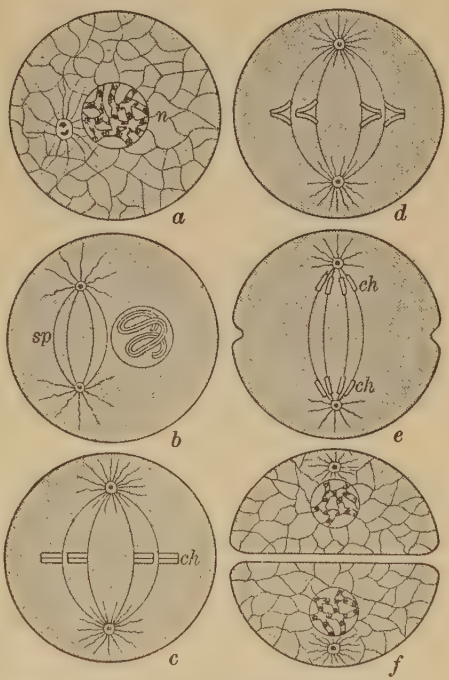


Fig. 13. Sketches illustrating cell division by karyokinesis

The chromatin, the heredity-bearing structure in the nucleus of the resting cell (*a*), divides into segments (chromosomes, *ch* in *c*); in *d* these divide lengthwise, in *e* they have migrated to opposite poles of the spindles (*sp*), and in *f* they form the nuclei of the new cells. *ch*, chromosomes; *n*, nucleus with its inclosed chromatin; *sp*, nuclear spindle along which the chromosomes travel

Heredity through various parts of the body. The heredity mechanism is in many organisms resident within diverse cells of the body. In the simplest forms of animals, such as the amœba, and in such low plants as the bacteria, the entire organism consists of one cell. Among these forms a common method of multiplication is by division (binary fission). In this process the

cell divides into two new cells, each of which receives half the nucleus of the old cell and half of each chromosome, so that each half contains the same heritable qualities. Since this is the method utilized in the growth of all many-celled individuals, each of the resultant cells should contain the heredity mechanism and the power to produce the complete many-celled organism. But this ability is surrendered as a part of the price paid to become a higher organism. The necessary subdivision of labor enters, and the ability to grow a new organism becomes more and more restricted to certain parts of the body. In many plants and in the lower classes of animals this power is retained in groups of cells in various parts of the body. If a willow branch is planted in damp soil, it will grow and produce seeds just as if it had been grown from a seed. A geranium stalk or a begonia leaf will do the same. In these cases it is evident that the heredity mechanism must be present in these stalks and leaves.

Fig. 14. Budding in the coral Heliophyllum from the Devonian period

In the coral Heliophyllum separate individuals have budded out from the sides of the parent cup (Fig. 14). It can be seen that these young individuals were self-supporting, and comparison with numerous living corals suggests that they could develop eggs which in turn would grow into new corals. Such a process of budding is the method used in the production of colonies in the lower animal classes, — sponges, hydrozoans, corals, and bryozoans. Since each individual animal in each of these colonies can produce eggs and thus give rise to separate individuals, the heredity mechanism must be present in these budded-off portions.

Closely associated with budding is the ability to grow again parts of the body that have been destroyed. This ability to regenerate lost parts is naturally more prevalent in the less specialized lower animals than in the higher ones. The starfish can replace lost arms (Fig. 15); the crayfish, lost claws and antennæ; the snail, lost eyes. In the higher vertebrates

this power is retained in the ability to regenerate nerves and to replace a small amount of lost skin and a smaller amount of lost flesh.

Heredity through reproductive cells. The heredity mechanism is resident within certain definite (reproductive) cells. Since plants and animals multiply by the development of reproductive cells, such as spores, seeds, and eggs, the heredity mechanism must reside in these. In the lower animals and in most plants, as we have seen, there is, accompanying this specialized condition, a retention of the more primitive condition whereby various groups of cells may cause multiplication of individuals. Higher animals are characterized by a greater number of organs and a greater refinement of function. In this increase in specialization the mechanism for carrying on the generations becomes gradually confined to certain restricted reproductive cells.

Fig. 15. Regeneration of a lost arm in the living starfish

Biparentage. In most cases in which the development of reproductive cells is limited to definite regions a union of two cells is necessary for growth. These cells are of two sizes, the larger of which is known as the female; the smaller, the male. In some cases, even in comparatively high forms, this union of two cells is not always necessary. Aphids, for example, through a process called parthenogenesis, may give rise to many generations all summer long without the presence of a male. In the fall, males also develop, and it is the fertilized eggs, resulting from the union of female and male cells, that are able to withstand the rigors of winter. Only cells of the same species, however, or of closely related species, can unite. Beyond that relationship a chemical or physical difference prevents union. This is true of all plants and animals.

Galton's law of heredity. Since the two reproductive cells are usually (in the highest plants and animals always) from dif-

ferent individuals, the heredity of both parents must be expressed in the next generation. This new individual thus inherits from each of its parents. Each of these parents inherited in turn from each of its parents, and thus back to the beginning of life. Hence each individual may be said, in a general way, to inherit one half of its traits from its parents (one fourth from each parent), one fourth from its grandparents (one sixteenth from each of its four grandparents), one eighth from its great-grandparents, and so back to its remotest ancestors. This inheritance of each individual from successively remote generations is expressed in the series $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, etc. and is known as Galton's law of ancestral inheritance. It has been shown, however, that this is merely an approximation to the truth.

Mendel's law of heredity. Both Mendel and Galton call attention to important principles of heredity. Mendelism considers a single pair of characters at a time, while Galton takes into account the sum total of an individual's inheritance. Mendelism shows that each individual possesses certain dominant characters and other recessive ones and that these are passed on through inheritance in the proportion of three dominant to one recessive. When, however, the entire inheritance of an organism is considered, an inheritance that becomes especially complex in the higher animals, the internal and the external characters are so numerous that the number of dominant characters and the number of recessive ones passed by each parent to its offspring appear to be approximately equal.

TOPICAL REVIEW

The fact of heredity.
The mechanism of heredity.
Heredity through various parts of the body.
Heredity through reproductive cells.
Biparentage:
  Galton's law of heredity;
  Mendel's law of heredity.

CHAPTER XII

EXTERNAL FACTORS OF EVOLUTION

Influence of environment. It is possible that the environment may stimulate organisms so as to cause the development of new variations. The parallelism between great and prolonged climatic changes and times of maximum appearance of new species suggests a causal relationship. This influence of the environment is called the Lamarckian factor in evolution (see Appendix, pp. 246–249).

Whether variations originate through crossing, through mutation, or through minute internal changes, or come into existence under the stimulus of the environment, their persistence is due to their being "selected." Selection is thus the principal external factor in evolution.

Artificial selection. When the selection is due to man, it is called artificial. When Burbank wished to produce a spineless cactus, he kept selecting and segregating, in each succeeding generation, those individuals which varied in the direction of fewer spines. Burbank was the environment which made the selection.

Concord grape. Since European varieties of grapes proved unsuccessful in this country, new kinds were evolved from the native stock, — in South Carolina, the Isabella; in Georgia, the Catawba. In New England, however, and throughout the north, the season was usually too short for the complete ripening of those varieties. Hence gardeners had long experimented to produce a grape that would ripen before the early frosts came. This was first accomplished by Ephraim Bull of Boston, a gold beater by trade, who was forced by ill health to retire to a small farm in Concord, Massachusetts. He had experimented with grapes all his life, but these, being of south-

ern varieties, were killed by the northern frosts. Finally he turned to the native northern stocks, using cuttings from many sources; the fruit, however, remained poor. He then planted ripe fruit from the wild Fox grape (*Vitis labrusca*), which grew luxuriantly on one corner of his farm and ripened early. For six years he nursed the many seedlings which arose from this first planting, and at the end of that time he found one plant of somewhat superior quality. This he nursed for five years more, increasing its size by cuttings. On September 3, 1853, he exhibited fully ripe grapes before the Massachusetts Horticultural Society. This new variety possessed the rich aroma of the Catawba, with which it is probable that its parent stock was naturally fertilized, and displayed likewise the early ripening and hardy qualities of the Fox grape. Within ten years after its first showing, this, the Concord grape, had spread over the country. In this example Ephraim Bull was the external factor which made the selection. When nature makes the selection, the result is said to be due to natural selection.

Natural selection. Natural selection is the factor usually referred to when Darwinism is mentioned. In Darwin's opinion the most important single cause of evolution, of the origin of new species, was the selective action of the environment in preserving the fittest. Those forms which varied in directions favorable to their preservation survived and reproduced. Those whose variations were not adapted to the conditions of the environment died without offspring. Selection has been called the pruning knife of nature. Darwin conceived this evolutionary agency when he read the essay by Malthus on population. Malthus had been led to this thought (that population tends to multiply faster than its means of subsistence can be increased) by reading the essay, by Benjamin Franklin, "Concerning Increase of Mankind." Franklin showed that mankind increases to the capacity of the food supply. Writing in 1751, he said there were then about a million English persons in North America, many of these

coming directly from England, and yet there were apparently just as many in England as there had been; also, that North America had been fully settled by hunter Indians, but was then becoming fully settled by agriculturists.

Rapidity of unchecked multiplication. The number of offspring of many plants and animals is enormous; yet even the slowest breeder among mammals, the elephant, would soon overrun the earth if its increase were unchecked. Darwin has calculated that a single pair of elephants, if they produced only six young during their lifetime and if these in turn continued to reproduce at the same rate, would, unchecked by accident, have nineteen million descendants in seven hundred and fifty years. The progeny of a single pair of English sparrows might in ten years amount to two hundred and seventy-six billions. One oyster may have 60,000,000 eggs a year. If we take an average yield for the American oyster to be 20,000,000 eggs and consider half of these to be females, the great-great-grandchildren alone of one oyster would, barring the accidents which normally hold the species in check, number ten octillions (10×10^{27}). This would form a heap of shells one thousand times the size of the earth. Plant lice (aphids) are very rapid breeders. The hop-vine aphis was observed to have thirteen generations in one year. If each female produced one hundred, and all individuals produced in the summer are females, the number in the twelfth brood alone would, barring accidents, be ten sextillions (10×10^{21}). If these were placed in a line, ten to the inch, touching one another, they would reach to a star twenty-eight hundred light years distant. That is, they would be developing at a rate incomparably faster than light travels.

Area of earth's surface and food supply constant. Since the area of the earth's surface (land and water) and the food supply (except for man) remain practically constant, there arises from this rapidity of multiplication the necessity of death. Because the earth is too small to give a home until adulthood to the offspring of even one generation of plants

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and animals, the unnumbered hosts of many generations could not be accommodated. It thus necessarily arose that "Life evermore is fed by death." There also arises the necessity of scavengers, especially such as bacteria and the fungi of decay, that the unconsumed dead bodies may pass quickly back into the inorganic elements of earth and air.

Number of organisms dependent upon food and protection. All animals and most plants depend, for their continued existence, upon the death of other plants or animals for part of their necessary supply of energy. Food is a primary factor in survival.

Before 1859 the potato bug, the black-and-yellow striped beetle that feeds on the leaves of the potato, subsisted entirely on the wild sand bur. This is a wild plant allied to the potato, growing in Colorado, Arizona, and New Mexico. Upon this the beetle was practically harmless, being kept in check by its parasites. The advance of civilization westward brought broad fields of the potato. This new food proving acceptable to the beetle, and the potato fields becoming so numerous, it multiplied enormously. Spreading eastward from field to field it reached the Atlantic seaboard in 1874. Since the parasites of the beetle could not multiply with equal rapidity, the number of beetles is now practically a balance between that of potato plants and the insecticides used by the farmers.

The cliff swallow, or eaves swallow, was found by the early explorers of the Yellowstone and other Western streams, building nests of mud beneath projecting cliffs. As settlers gradually worked their way westward these swallows found nesting places under the eaves of buildings, where they were better protected than on the cliffs. Following the settlements eastward, they reached Ohio in 1815 and Maine in 1830. Thus, because of the increase in the number of protected building sites, the swallows increased enormously in number. They reached their maximum in the Eastern states between 1840 and 1860, after which they were gradually reduced in number by the English sparrow, which had been

introduced into Brooklyn, New York, in 1851, to feed upon the geometrid caterpillar.

This law of numerical increase to a balance between food supply and protection holds true for mankind. Java, in 1825, when the Dutch assumed control, had 5,000,000 inhabitants; in 1905 it had 29,000,000. In pre-English days Egypt had 7,000,000 inhabitants; in 1899 it had 9,750,000. In both cases the increase in number was due largely to the increase in arable land through irrigation and to the better protection of life. In England, from 1480 to 1800, the increase per decade was 2.5 per cent; from 1800 onward it was 13 per cent. The nineteenth century saw the beginning of the large manufacturing establishments and hence a tremendous increase in the importation of food. In 1901 there were 45,000,000 more inhabitants in India than in 1872, mainly because of the great increase in arable land due to irrigating works, and the stoppage of inter-Indian wars. Yet the bad crops of 1896–1897 and 1899–1900 caused, in spite of the better transportation facilities, the death of 21,000,000, people.[1]

Detrimental change in climate is but one of the many enemies by which organisms are menaced. Numerous parasites feed upon both plants and animals, many of which produce infectious diseases. Every organism upon earth has many enemies. In central Europe alone the willows are menaced by 396 species of insects, the oaks by 537 species; besides insects, there are many species of fungi etc. which may destroy vitality.

Struggle for existence. Food and protection, which includes freedom from enemies, are essential to rapid multiplication; but multiplication of any species, unchecked by enemies, would lead to the destruction of its food supply and thus to the destruction of the species. Thus we arrive at the paradox that the continuance of a species from generation to generation is dependent upon the presence of enemies. Without enemies no food would remain for succeeding generations. Thus every

[1] C. E. Woodruff, Expansion of Races.

part of the earth supports as many living beings as can find food; that is, the earth is always saturated with life.

The rapidity of unchecked multiplication of all organisms, accompanied as it is by the necessity of food and the presence of numerous enemies, would naturally tend toward the preservation of the individual in which occurred any change that in the least degree enabled it to get more food or to escape its enemies more easily. When such helpful changes are passed, through heredity, to the offspring, they persist. This is accompanied by the destruction of the individuals least suited to that particular environment. If the best variants were

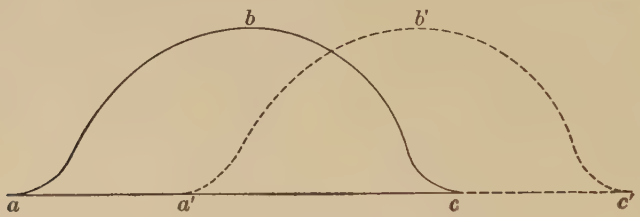


Fig. 16. Diagram illustrating selection

numerous enough, this elimination of the unfit in each generation would gradually result in the evolution of a new species. In the life curve of a species, *a*, *b*, *c* in Fig. 16, let *a* represent the weak animals and *c* the strong ones. The vast majority, *b*, will be intermediate. Of the offspring of the species a few will be as weak as *a*; a few as strong as *c*. The weak ones will be the first to perish in the competition which ensues upon a scarcity of food. During an epidemic disease the weak will be the first to succumb. Hence, as the individuals at the *a* end of the curve have died and those at the *c* end have survived, the curve will advance to *a'*, *b'*, *c'*, that is, beyond the strong end. And thus it will continue advancing with each succeeding generation. Now let *c* in the curve represent fish with slightly better fins, or stronger skeletons, or larger brains, than *a*. In competition such will survive and, if the change is heritable, will transmit to their descendants that which

enabled them to compete so successfully. The curve thus progresses to the strong side. This principle, according to which useful variations tend to the preservation of the individuals possessing them, is that of natural selection, or the survival of the fittest.

This curve, however, will branch in all directions according to the necessities of environment. Every class of animals will spread into those environments where food may be obtained and where escape from enemies is possible. Certain species of worms, for example, burrow in the earth, where they live principally upon vegetable mold; others build tubes in which they live and catch such food as floats by them. Still others are free swimmers, active and predacious. As the environment of these different species differs, so necessarily will their manner of development differ.

If a species occupies a wide territory, characterized by differences in food, temperature, chemical content of water or air, enemies, etc., variation will naturally take place in different directions. C. B. Davenport has shown that this evolution is now taking place in the scallop (*Pecten irradians*), living off the Atlantic coast from Long Island, New York, to Pensacola, Florida. Those shells differ most that are most widely separated geographically. These scallops have not been able to interbreed. The same is true of *Pecten opercularis*, living off the coast of Great Britain. Those from near Edinburgh differ most from the ones living in the Irish Sea, and less from those off southern England. In these cases geographic segregation aids the evolution of new forms by preventing interbreeding.

The evolution of the horse occurred during the Cenozoic upon the open plains of North America. As the mountains to the West were rising the plains became drier, thus compelling the horses to travel farther for food. Since in this situation the principal factor in survival was speed, variations that favored rapid traveling tended to be preserved. Thus the life curve would move in the direction of a longer and narrower

leg, and of increase in the size and reduction in the number of toes. During the Cenozoic the horse evolved from the four-toed Eohippus to the one-toed Equus, from the Eocene horse, one foot high, to the modern horse, five feet high.

The carnivores which fed upon the animals of the open plains must necessarily have kept pace with them in the development of quickness and speed, for otherwise, without food, they would have ceased to exist. The fossil bones of these carnivores are seen to become longer and more slender, paralleling the evolution of the horse and other herbivores of the open plains. The speedier carnivores would in the meantime kill off all the slower, less evolved horses, which continued to find food either in the forests or along the perennial stream courses of the plains. Hence, as the fossils show us was the case, the life curve of all horses, whatever their habitat, would vary in the direction of greater speed. Yet throughout all this time, because the horses occupied a very large territory, the various environments brought about the selection of a great variety of species.

Balance in nature. Since throughout nature the continuance of one species depends upon the presence of one or more other species for its food supply, it follows that a more or less perfect interlocking balance is always present. Disturb one link of this chain, and far-reaching changes must result.

A scale insect was accidentally introduced into California on some lemon trees from Australia. It multiplied so rapidly as to threaten the destruction of the California orchards. Search in Australia revealed the fact that a species of ladybug is the natural enemy of this scale insect. This was imported and had soon multiplied sufficiently, under the great abundance of its food, to destroy nearly all the scale insects. Thus deprived of its principal food, the ladybug was threatened with extermination. To insure against some future outbreak of the scale-insect pest, protected colonies of the scale insect and ladybug are now kept in readiness.

Darwin long ago suggested the linkage between domestic cats and red clover. Cats eat field mice, which destroy the nests of bumblebees, which fertilize red clover. It is well known that near villages the bumblebees are more numerous than in the open country. An increase in the number of cats thus leads indirectly to an increase in clover.

In the great struggle for existence, each perpetuating form of life that we call a species is really an expansive force, that can be restrained and kept in its proper place only by the similar expansive forces (other species) by which it is surrounded. It is as if the whole field of animal and vegetable life consisted of a series of springs, each exerting a pressure in all directions, and each held in place only by the similar expansion of the springs surrounding it. This action and reaction of natural forces constitute what is known as the balance of nature. Any serious disturbance of this balance is always fraught with serious consequences.[1]

TOPICAL REVIEW

Influence of environment.
Artificial selection.
Natural selection:
- Rapidity of unchecked multiplication;
- Area of earth's surface and food supply constant (for majority below man);
- Number of organisms dependent upon food and protection;
- Struggle for existence (survival of the fittest);
- Balance in nature.

[1] E. H. Forbush, Useful Birds and their Protection.

CHAPTER XIII

PARASITISM

Commensalism versus parasitism. Commensalism in its broad sense is an association of organisms in which each contributes to the welfare of all, while in parasitism one receives but contributes nothing. The association of man with man is normally commensalism, as is also that of man and domestic cattle, as each contributes to the general welfare. This is true of the relationship of many ants and aphids. The ants take the larvæ of the aphids into their burrows, where they are protected from enemies and cold. After hatching in the early summer, they are herded by the ants to the proper kind of plants. Here the aphids secrete a honeylike fluid which is consumed by the ants. There is the same association here as between man and milch cattle.

A parasite, from the viewpoint of biology, is a plant or animal that lives in or upon some other living organism (called its host), at whose expense it obtains its food.

Abundance of parasites. It has been estimated that one half of all animals are parasites. Plant parasites are also numerous. Their abundance is due to their minute size and great rapidity of reproduction.

Not a single living species of plant or animal is known that is free from parasites. In central Europe it was found that there were 270 species of insects injurious to the birches, 396 to the willows, and 537 to the oaks, and that many of these were parasites, such as scale and gall insects and plant lice. Besides insect parasites there were many others, especially fungi. Over fifty kinds of galls have been described from willows alone. Galls are due to the injection of some substance into the plant tissue, especially the leaves or stems, which

produces a swelling somewhat like that which the sting of a bee causes in animal tissue. Almost no form of plant life is exempt from galls; they occur even on gymnosperms, ferns, fungi, and algæ.

Many species of fungi parasitize other parasitic fungi. All members of one genus of ichneumon flies live at the expense of wood-boring larvæ of other insects and are fed upon in turn by still other insects. Some insects are so minute that they breed in the eggs of other insects, while some parasitic protozoans make their edible home within the nucleus of other microscopic protozoans.

Thus parasites form a large portion of the life of the earth, and under the influence of variation and natural selection they, like all other organisms, adapt themselves to new environments.

Origin of parasitism. The development of parasitism is a relatively simple process. In plants this involves the change from forms which derive food from soil mixed with dead organic matter to such fungi as live entirely upon dead plants and animals, and to those that penetrate living plants such as bracket fungi (true parasites). Among animals the change is even simpler, as animals have from the beginning depended for all their energy upon other animals or plants. The ox eats the grass, and the caterpillar the leaf. Since these animals are under the necessity of moving freely in search of food, there is no degeneracy; they are not parasites according to the definition. Neither are such sessile animals as corals called parasites, although, like all sessile animals, they are degenerate. They consume both living and dead animals, but they do not dwell upon or within a single one of these. They live a life independent of that which forms their food. Plant lice (aphides) are probably on the border line. They wander freely about the plant for places from which to suck the juices, but are usually confined to a single plant. In the scale insects it is only the young that move about the plant in search of a place to settle; after that they remain stationary.

Hence, when they have killed the plant, they also must die. This is true parasitism. It is natural that some small animals and plants should attack organisms much larger than themselves for food. The large organism then reacts so as to get rid of the attackers. This necessitates some physical or chemical change in the latter if they are to survive. Gradually both host and parasite become so changed that the latter can live only upon that particular species.

Large plants and animals have through the ages of their evolution developed new means of getting food and new means of defense against both their larger enemies and their microscopic enemies (parasites). In this struggle both sides have adopted a number of ways of overcoming each other's attacks. Two of these methods are the development of a protective covering and the secretion of poisons. The host through ages of adaptation evolves tissues incapable of entrance by the parasites of that time, and develops antitoxins to neutralize the poisons given out by them, while the parasites acquire new means of penetration and new toxins.

As a result of such interaction species of parasites have become confined to very restricted feeding grounds. A species of parasite may be confined to a single species of plant or to a single organ of one species of animal. One large group of protozoans is almost entirely confined to the red blood corpuscles of the vertebrates, another to the cells of the digestive organs. Some species are confined to the spleen, some to the kidneys, others to the liver. One kind is confined to the poisonous nightshade plant, another to the bitter leaves of the oak, while another can live only on the clover. A given species of bird lice is usually confined to the feathers of a single species of bird. At times the same species occurs on one species of bird in the Old World and on a related bird in the New World, indicating that evolution has been less rapid in the parasite than in the host. Among plant parasites we see the same restriction in the hollyhock rust, the coffee fungus, the blister blight of tea, asparagus fungus and

chestnut fungus, the gooseberry mildew, the oat smut, various kinds of wheat smut, barley smut, and the potato-leaf blights.

Paleontology of parasites. Parasites are known from at least the Devonian to the present (Moody's volume on "Paleopathology" gives much information on this subject).

Fossil bacteria are known from the Proterozoic. Those causing decay (but not parasitic) are found in wood and vertebrate bones from the Devonian, but it is not until the Permian that we find good evidence that some of them had become parasites. Here their presence in the coprolites (fossil fæces) of fish, amphibians, and reptiles indicates that they were parasitic in the alimentary canal. The earliest known parasitic fungi are spot fungi on foliage from the Devonian. Bracket fungi occur from the Tertiary to the present.

Insect parasites are well known from the Cretaceous to the present. These include leaf miners and galls. The parasitic myzostomid worms, many species of which are today external parasites on crinoids, had evolved apparently by the Carboniferous. In this period tumorlike lesions are found on crinoid stems.

Man has supported parasites from the time of the Pleistocene. During this period he had decayed teeth and pyorrhea. Much later the ancient Egyptians, as seen from examination of their mummified bodies, suffered also from tuberculosis, pneumonia, smallpox, and renal abscesses.

Temporary parasites. Many animals are parasitic during only a portion of their life and free-living at other times. The majority of parasites from the higher classes, such as mollusks and arthropods among animals and seed bearers among plants, belong here. In many insects the parasitic part of the individual life history is confined to the early portion; in such crustaceans as Sacculina the adult only is parasitic.

One species of the numerous ichneumon flies thrusts its eggs into the caterpillar of a sphinx moth. Here they hatch and the young larvæ feed upon the nonvital portions of their host. When fully grown each breaks through the body wall

and spins a cocoon upon the outer surface of its host just before this host dies. Here they look like a number of short white clubs projecting from the surface of the green caterpillar. Soon the young emerge from the cocoons as adult ichneumon flies whose life from now on is free.

In the crustacean Sacculina it is the young which is free, while the adult represents the nadir of parasitism. In its youth it is free-swimming, looking very much like the young of barnacles; but after a brief free existence it fastens itself to a young crab and, casting off its carapace and appendages, bores into the body of its host. Throughout the body it sends long, rootlike processes by means of which it absorbs nourishment from its host. After growth to adulthood it looks like a tumor on the abdomen of the crab, with absolutely no resemblance to a crustacean.

Permanent parasites. In an advanced stage of parasitism the organism has no free stage in its career. These are more abundant in the lower classes, such as protozoans and worms among animals and bacteria and fungi among plants.

In the human tapeworm (*Tænia solium*) the eggs with their inclosed embryos escape from man with the fæces If these are taken into the alimentary canal of the pig, the embryos bore their way, by the aid of hooks, through the wall and into the voluntary muscles. If a portion of a pig's muscle containing one of these, which has not been killed by cooking, is taken into the human stomach, the worm attaches itself to the walls of the intestines by means of its hooks and develops into the adult tapeworm.

The tapeworms are thus parasites throughout their life, the youthful stage being passed in one animal and the adult in another. The former animal is one of the common foods of the latter. The adult stage of one tapeworm is passed in the cat, and its youthful stage in rats and mice; another rotates between the dog for the adult stage and hares and rabbits for the youthful stage. Man and the pig form the hosts of another species, man and the ox for another.

One class of protozoans, the Sporozoa, which are entirely parasitic, has representatives infesting animals from Protozoa to man, including every class of vertebrates.

Infectious disease. Many species of permanent parasites produce communicable diseases. There must, of course, be some means of transfer of the organisms from host to host. This is usually by physical contact, by the air for short distances, by insects for greater distances, and by food. Thus it is that the vast majority of these parasites are one-celled plants and animals. Disease is the result of a contest between the invading cells and the cells of the host for food and existence, or it is due to some poison secreted by the invaders. In man different species of bacteria (one-celled plants) cause tuberculosis, bronchopneumonia, typhoid fever, Asiatic cholera, diphtheria, tetanus, influenza, dysentery, and erysipelas, while protozoans produce dysentery, typhus fever, pernicious malaria, syphilis, and sleeping sickness.

The lower animals, as well as man, are subject to diseases. Insects, mollusks, and fish are especially liable to the ravages of contagious diseases. Pathogenic protozoans cause vast epidemics among silkworms, fish, and domestic animals. Diphtheria and tuberculosis destroy very many birds and beasts, the bacteria being different species from those attacking man.

Effect of parasitism on the host. The direct effect of parasitism on the host is a harmful one. Part of it is consumed as food, while the poisons developed by many species of invaders upset its normal metabolism. If it would survive, the host must get rid of the invading parasites and reëstablish normality in the body. One means to this end is the development of substances (antibodies) antagonistic to the parasites or their poisons. Thus the indirect result of parasitism is a change within the host. Dr. Eccles compares the structures and shapes of flowers which have been molded into accommodation for insects to the internal organs of all higher forms of animals which have had their structures modified through opposition to parasitism. There is no part of a body that

has not needed some sort of immunity against attack. That bodies have developed it is proved by the fact that the host is still alive; for in an epidemic of any disease only those would reproduce their kind whose bodies had developed some means of overcoming the foreign microörganism or its poison.[1]

Effect on the parasite. The effect of parasitism on the para site is for all higher forms a specialization leading to degeneracy. The nervous system, locomotor organs, and external skeleton degenerate. The lower orders, not having so far to fall, naturally show this degeneracy least. The tapeworm has lost all trace of an alimentary canal; the dodder amongst seed-bearing plants has lost all chlorophyll. In each case food ready for use forced from the host has led to degeneration.

Parasites as a factor in natural selection. It is thus apparent that parasitism is an important factor in evolution. A parasite and its host react upon each other so that each must gradually change if it would survive. Each is one of the natural-selection factors in the case of the other.

TOPICAL REVIEW

Commensalism versus parasitism.
Abundance of parasites.
Origin of parasitism.
Paleontology of parasites.
Temporary parasites.
Permanent parasites:
  Infectious disease.
Effect of parasitism on the host.
Effect on the parasite.
Parasites as a factor in natural selection.

[1] Dr. R. G. Eccles treats parasitism from the viewpoint of natural selection in the *Medical Record*, Vol. 76, pp. 169–177 and 757–765; also in Vols. 80, 81, 83, 88, etc.

CHAPTER XIV

ADAPTIVE RADIATION

The energy of life pushes out through varying forms in directions determined by the stimulus of the environment and the limitations of heredity. Derived from the same remote ancestor came the huge, slow dray horse and the fleet race horse of today. Their environment, embodied chiefly in man, developed them for strength in one direction and for speed in the other, while their common inheritance endowed these two superficially different forms with the same basic plan.

THE LAW STATED AND ILLUSTRATED

For the mammals Osborn has formulated the principles under which this radiation occurs somewhat as follows: In each large, isolated region, varied in topography, soil, climate, and vegetation, the mammals will radiate in different directions mainly through changes in the structure of (1) feet (correlated chiefly with limb and body structure) and (2) teeth (correlated chiefly with skull and neck structure). Variations which enable an animal to escape its enemies more efficiently, to get food, or to raise offspring are naturally utilized. Such variations will tend to be passed on by inheritance if the region is sufficiently large and varied to prevent too close interbreeding with the normal ancestral stock.

Radiation in limb and foot structure. Such changes in limb and foot structure will gradually lead to (1) more rapidly running forms, (2) flying forms, (3) water dwellers, and (4) forms burrowing in the earth. Adaptive radiation is more marked and varied in cases in which the common ancestor is of primitive, generalized structure. A study of fossil forms shows that radiation has characterized life from its inception

on earth to the present. It has given us the great variety of plants and animals which are now living upon the earth, with their varying shapes, colors, and traits, besides unnumbered myriads of other forms which have become extinct.

Fig. 17. Radiation in foot, limb, and general body structure among mammals

To illustrate the four main lines of adaptive evolution, namely, into water, into air, into the earth, and upon the surface of the earth. The forms listed are cited merely as examples of the sequence of modifications of limb and foot in the evolution of mammals

The examples in Fig. 17 are drawn from the higher mammals, the common ancestor of which is supposed to have been an early form of the very ancient order Insectivora. This ancestral form is typified by Gymnura of the Malay region, the most primitive living insectivore. From some such form (probably of the late Mesozoic) radiation has proceeded to the present. Divergent variation in the shape of the teeth has complicated this evolution (see Fig. 19); for when teeth begin to become specialized in some direction, as for cutting, grinding, or gnawing, change in this direction is persistent and exclusive of other variations.

Radiation of marsupials. In the Australian region there is an interesting example of radiation. This region was cut off from other continents at a very early date, probably at the close of the Mesozoic. At that time the marsupials were the highest animals in the region, and had thus an opportunity to branch in various directions in their search for protection and food, undisturbed by incursions of higher animals evolved upon the larger continents.

The ancestral form which gave rise to the wide diversity of Australian marsupials was apparently an animal closely allied to the opossum, — the most primitive living marsupial. Although this is an American, tree-dwelling form, it is extremely old, with near relatives in the Cretaceous rocks, and may hence have been present in the Australian region during the late Mesozoic. It is still very primitive, as is shown by the limitation of its tree-dwelling adaptation to the development of a prehensile tail and a grasping hallux. Many of the Australian marsupials also, such as the phalangers, have a prehensile tail and opposable hallux.

The marsupials parallel in a remarkable manner mammals of other orders, similarity of habitat and food bringing about a superficial similarity of form. Thus one Koala is lemur-like; Dasyurus, marten-like; one of the bandicoots, rabbit-like both in form and habits; and the flying phalanger resembles the flying squirrel in its parachute-like expansion of skin

between the fore and hind limbs. There are apparently no water-dwelling marsupials in this region; there is, however, a water opossum (Chironectes) in Central and South America.

Fig. 18. Radiation among the marsupials of the Australian region

Radiation in tooth structure. Not only does the structure of feet, limbs, and body become so modified that mammals may live in widely varying habitats, but adaptive changes take place also in tooth structure. This confers an ability to live upon different kinds of food. Among the higher mammals the

tooth and head structure of the order Insectivora is the most generalized, combining characters separate items of which are accentuated in distinct groups of descendants. The teeth of the typical insectivore are low-crowned, with few cusps to each tooth and sharp-pointed, such as are suitable for crushing soft prey. Some descendants tended to develop more or less flat-crowned molar teeth (ungulates); others, chisel-shaped incisors (rodents); others, sharp cutting premolars and molars and rending canines, the fangs (carnivores). In another

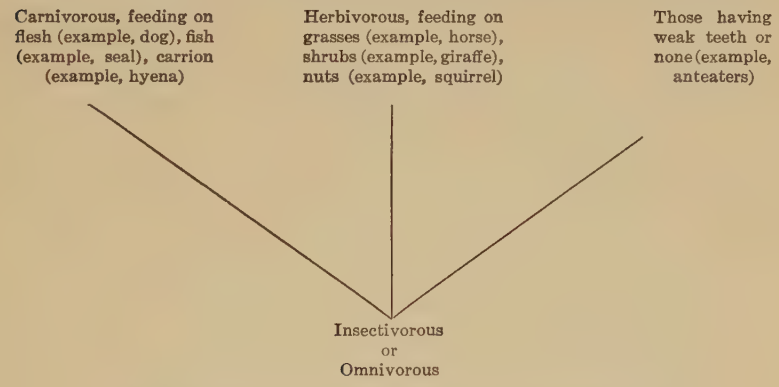

Carnivorous, feeding on flesh (example, dog), fish (example, seal), carrion (example, hyena)
Herbivorous, feeding on grasses (example, horse), shrubs (example, giraffe), nuts (example, squirrel)
Those having weak teeth or none (example, anteaters)
Insectivorous or Omnivorous

Fig. 19. Radiation in tooth structure among mammals

direction (forming the order Edentata) the teeth tended to disappear; they are imperfect and without enamel in the adult, or (in the anteaters) entirely wanting. Each of these greater groups includes many subdivisions. For example, among the carnivores, those that are eaters of fish have all the teeth more or less fanglike; in the flesh eaters they are better adapted for rending and cutting, while the carrion feeders have comparatively blunt teeth. Such marine mammals as the seal and the whale, which have descended from land forms, have more simple, fanglike teeth when fully grown than they possess in the embryo. The teeth with two or three cusps in the younger embryo apparently split up into the later more numerous simple cones.

BODILY CHANGES RESULTING FROM ADAPTIVE RADIATION

It is seen that changes take place in the same general direction among animals entering similar habitats. These new adaptations are, however, impressed upon the special type of substructure possessed when entering this habitat. The seal and whale have merely the external shape of a fish, as the bat resembles a bird. Each, in short, may change to the extent permitted by its heredity.

Adaptation to running. The changes in the skeleton that lead to increasing speed in running include the following: (1) A change from a plantigrade (flat-footed) condition, as in the bear and man, to a digitigrade one (running upon the toes), as in the cat and dog, and finally to an unguligrade state (resting upon the tips of the toenails), seen in the pig, deer, and horse. (2) A loss of the side toes. (3) A reduction in the size of one of the bones (fibula and ulna) in each of the limbs. These three changes bring about a lessening of the weight to be lifted and thrown forward at each stride. (4) A lengthening of the limb bones and hence of the stride. Changes (2), (3), and (4) are well illustrated in the evolution of the camel and horse. (5) A change from a four-footed (quadrupedal) to a two-footed (bipedal) condition. Such an evolution has occurred at least eight separate times. Among the dinosaurs of the Mesozoic it occurred in both the herbivorous and the carnivorous group. The dinosaurs, using the huge tail as a counterpoise to the weight of the fore part of the body and resting upon the toes of their hind feet, were doubtless able to get over the ground at a rapid rate. Some lizards of today, such as Chlamydosaurus of Australia, have this bipedal and counterpoise carriage when they wish to go rapidly. Such a habit is also seen in the kangaroo among the marsupials and in the jumping mice and jerboa among the rodents.

Adaptation to a life in air. The ability to sustain the body in the air, for at least a limited period, was evolved many times.

It was acquired by the insects in the late Paleozoic, by the reptiles and birds in the Mesozoic, and by the mammals in the Tertiary. Flying fish are known from the Triassic to the present, while flying amphibians appear to be limited to the present. The necessary bodily changes accompanying such an adaptation include (1) a sustaining surface, (2) a keel upon the breastbone, and (3) hollow bones.

(1) The sustaining surface consists of greatly enlarged pectoral fins in flying fish; of huge feet with webs between the toes, besides a slight extension of skin at the sides of the arms and sides of the body, in the tree-dwelling "flying frog of Borneo" (Rhacophorus); of a similar arrangement in the flying or fringed gecko (a lizard of the Malay region); and of a similar extension of skin between the fore and hind limbs and the sides of the body in such mammals as the flying squirrels and flying phalangers. In many of these there is practically no lifting power, the "flying" consisting only of parachuting. In the insects, pterosaurs, birds, and bats true flight was developed. In the pterosaur reptiles and in the bats the sustaining surface consists of a leathery membrane developed between the fore and hind limbs and the sides of the body. This membrane is very much enlarged by the greatly elongated little (fifth) finger in the pterosaurs (confined to the Mesozoic) and the elongated second to fifth fingers in the bats. In birds the sustaining surface consists of feathers extending backward from the arms. In the remaining great class of true fliers, the insects, the supporting surfaces, the wings, comprise expansions of the chitinous skin stretched over chitinous tubes (the veining), carrying air and blood. (2) The keel upon the breastbone supplies the requisite additional surface for the attachment of the greatly enlarged pectoral muscles, so necessary in flight. (3) Hollow bones not only lighten the weight of the animal, but in different forms, such as birds and possibly the extinct pterosaurs, they provide room for extensions of the lungs, giving a much better breathing apparatus and hence an increased power for long flight.

Adaptation to a life in water. Since water is considerably more resistant to movement through it than is air, the body tends (1) to develop a more or less spindle-shaped contour. This is typically seen in the fish and is true of any form that moves actively through the water, — the squid among cephalopods, the ichthyosaur among reptiles, penguins among birds, and whales among mammals.

Another bodily change among the vertebrates is (2) locomotion by means of fins or paddles and usually also by lateral undulations of the posterior portion of the body. These may be observed in ideal development in such diverse classes as the fish, the ichthyosaurs among reptiles, seals and whales among mammals, and penguins among birds. In all of these, except the fish, the anterior limb has become a very efficient paddle.

Adaptation to a life within the earth. Since the earth is much more dense than water, few animals have evolved the ability to move freely within it. Such evolution was accomplished among the mammals by the insectivorous mole and the marsupial mole. In these the contour of the body is somewhat spindle-shaped, with loss of all unnecessary projections. It is so molded externally as to offer the least resistance to the medium through which it passes. Many animals burrow into the earth for their homes, usually getting their food upon the surface of the earth but going into it for protection, sleep, and the rearing of young. These more or less permanent homes are holes or tunnels. To this group belong ants and some crabs among the arthropods, some snakes and lizards among reptiles, bank swallows among birds, while in the mammals many orders have representatives. Such are the entire monotreme order, many marsupials (as the kangaroo-rat), the armadillo among the edentates, and the water shrew of the insectivores; among the rodents are the rabbit, the woodchuck, and the ground squirrel, and among the carnivores the otter, the skunk, and the badger. It is very natural that both the insectivore and rodent orders should evolve many individuals which took to the earth for a habitat, the former

through searching for grubs and worms, and the latter in feeding on roots, the chisel-shaped incisor teeth forming excellent digging implements.

Hibernation. Within the temperate and the colder regions winter brings about a cessation of plant growth, and this is followed by the disappearance of most insect and bird life. There is consequently a great reduction in the food supply of such animals as do not migrate. Freezing temperature would necessarily stop the movement of all cold-blooded land animals, since upon the surface of the ground they would be frozen solid. Thus it is that all cold-blooded land animals and many warm-blooded ones pass the winter in a quiescent state. During this hibernation the breathing and heartbeat are slowed down very greatly. The normal heartbeat of fully grown snails is from 30 to 100 per minute; during hibernation it is not more than twice a minute.

The development, among animals, of an ability to hibernate (and this is especially true of mammals) depends primarily upon the storage of food within their tissues and the very slow utilization of this food. This result is accomplished by a sleep so deep that all muscular movement ceases, except for the necessary slight breathing and heartbeat. The woodchuck is very fat in the fall, but in the spring, after his long sleep, his skin is much too large for his contracted body and hangs in loose folds.

Some warm-blooded animals subsist during the winter upon food stored up outside the body. The squirrel has storehouses above the ground, and the chipmunk in burrows beneath the surface.

Adaptation to a life in the dark. 1. *In caves.* Partly because of the safety afforded to many animals by darkened caves, and partly from a previous deterioration of their eyesight, dark caves have become tenanted. Caves are abundant and extensive in all limestone regions. In Edmonson County, Kentucky, alone, five hundred caves are known, while Mammoth Cave, Kentucky, is ten miles long and its winding

caverns cover a distance three times as great. The present caves of at least eastern North America probably did not come into existence before the Pleistocene, for the oldest fossils found in them are of Pleistocene age. They were developed because of the lowering of the ground-water level through the down-cutting of the streams which followed the uplift of the Tertiary partial peneplain during the Pliocene.

Within these caves are found living normal, partly blind, and completely blind animals. The normal ones live at the entrance, and the completely blind in the dark interiors. The deep interior cave faunas include among the arthropods blind crayfish and blind crickets; among the amphibians, blind salamanders and blind fish. Since many catfish living in open streams have defective eyesight, it is not strange to find some partly blind ones in the caves. Most cave fish, however, belong to one family, the Amblyopsidæ. All members of this family, of several genera and species, have degenerate eyes, whether living in open waters or within deep caves. In the latter places only do the completely blind forms live.

The principal bodily changes brought about by a life in a dark cave are (*a*) bleaching; (*b*) deterioration of eyesight; (*c*) the development of special sense organs over the body for the location of the slightest movement in the water; and (*d*) reduction in size, especially in girth. This change is doubtless due to the scarcity of food.

2. *In abyssal seas.* Water of abyssal depth is characterized by the absence of green plants and by scarcity of other food. These deep waters are very quiet, the cold is intense (about 35° F.), there is a scarcity of oxygen and an enormous pressure. Normal pressure at sea level is fifteen pounds per square inch. This is increased by about one ton per square inch for each thousand fathoms of depth. The oxygen is brought by the exceedingly slow creep of the abyssal waters toward the equator. Because of the cold the polar waters are the heaviest of all ocean waters, and hence sink, carrying with them the normal oxygen content of surface waters. It is upon this that

abyssal animals largely depend for their necessary oxygen. Since plants cannot grow below a depth of about 100 fathoms, deep-sea animals must depend for their primary source of food upon such organic remains as sink from the surface waters. These are largely microscopic forms of protozoans, pteropods, and diatoms. Upon these feed the bottom-dwelling sponges, worms, stalked crinoids, and mollusks; and these in turn form the food of starfish and fish. All animal phyla have representatives in the abyssal seas, but all are sluggish and small because of the scarcity of food and oxygen and because of the enormous pressure.

Organs producing phosphorescence, or light, often characterize abyssal animals. They are not present in dark-cave dwellers, as caves are too short-lived to permit of their evolution.

Biological significance of coloration. Some colors in animals appear to have no survival value. They are entirely concealed throughout the life of the individual, and it would seem that natural selection could have had nothing to do with their persistence. This is the case in many of the brilliantly colored Cypræa shells and the inner surface of Haliotis. On the other hand, some colors are of obvious value to their possessors. The arctic, or varying, hare, arctic fox, and ptarmigan are clothed during summer in brown, — a color that renders them inconspicuous against the bare earth and dead grass, while in winter they become white like the snow over which they travel. Desert animals are apt to be dun or gray in color, while forest dwellers, like the fallow deer, often wear a dappled coat resembling splotches of light among the shadows.

Any change in color which tends to obscure the animal from either its enemies or its prospective animal food would naturally help it to live longer and hence enable it to pass this quality on to a greater number of offspring, while those not so colored, other factors being equal, would tend to die out. In brief, animals frequently tend to be colored so as to appear nonexistent. There are two ways in which this may be accomplished.

a. Strong, arbitrary patterns of color tend to conceal the wearer by destroying his apparent continuity of surface. The adult Malayan tapir is black with a broad white band encircling the body between the fore and hind legs and covering the haunches. When he is lying down during the day near the rocky streams of the hill jungles, the white of his rounded back exactly resembles a gray bowlder. The baby tapir, on the other hand, is striped and spotted with white on a black background. During the day it lies under bushes, and in that situation it is so like a patch of ground flecked with sunlight that it is quite invisible.

b. When nature paints an object darkest on the part that tends to be most lighted by the light of the sky, this object appears nonexistent. Normally an object, such as a tree limb, is colored alike on all sides but appears to be lighter-colored on the upper side because of the light of the sky, and darker beneath because of the shadow. In our experience this gradation from light above to dark below is associated with solidity. Hence, if an object is painted darker above and lighter beneath, it does not seem to exist. Crouching birds, for example, such as the grouse, woodcock, and partridge, are darker above and lighter beneath, and when standing quietly they are almost invisible. The backs of such birds are often also speckled with a few light feathers among the dark, thus resembling the lights and shadows cast upon the ground by the light filtering through the leaves.

At times colors are of value as signals of warning that the wearer is poisonous or unpalatable. Such are the conspicuous yellows and blacks of the poisonous hornets and the reds and blacks of the unpalatable monarch butterfly.

Mimicry. Where safety results from a resemblance to some other organism that is feared or despised, the result is called mimicry. When startled, many species of geometrid caterpillars (measuring worms or loopers) erect themselves stiffly and pass for twigs. The palatable viceroy butterfly mimics the unpalatable monarch.

TOPICAL REVIEW

The law stated and illustrated:
- Radiation in limb and foot structure;
- Radiation of marsupials;
- Radiation in tooth structure.

Bodily changes resulting from adaptive radiation:
- Adaptation to running;
- Adaptation to a life in air;
- Adaptation to a life in water;
- Adaptation to a life within the earth;
  - Hibernation;
- Adaptation to a life in the dark;
  - In caves;
  - In abyssal seas;
- Biological significance of coloration;
- Mimicry.

CHAPTER XV

ORTHOSELECTION AND ORTHOGENESIS

Evolution may carry a species for a long time in certain definitely limited directions. This is evidently due to the continued existence of causes or stimuli, either within or outside of the organism, which initiate and tend to preserve certain definite lines of variations. Such development in straight lines is called orthoselection when the causes of the change seem to be due to factors in the external environment. It is called orthogenesis when its origin is ascribed to internal factors. Long-continued inheritance of "development along definite lines" apparently leads to stabilization, — to an inability to develop otherwise than in those particular directions. A certain trend becomes a hereditary habit.

The rise of lands after the close of the Cretaceous Period brought into existence broad areas of grasslands, and watering places became more and more distant. There thus arose a place in the economy of nature for speedier herbivorous animals. There is no doubt that the stimulus toward speed thus supplied by these regions was a most important agent in the evolution of the horse, camel, and deer. The lengthening of the median toes and the reduction of the side toes, once begun in these animals, were never reversed even by those descendants living in moist regions.

ORTHOSELECTION

Causes of orthoselection. The environmental influences which may favor evolution in a definite direction for a long time are very numerous. They include growing aridity and its opposite, the oncoming of a glacial period and its disap-

pearance, differences in the chemical content of waters, variations in the composition of the soil, the gradual change of a forested region into a prairie, and increase or decrease in the altitude of a large region.

Effects of changing climates. Among the external factors one of the most important from an evolutionary point of view is climate. Climate is defined by R. D. Ward as "average weather," the fundamental control of which is the sun. Solar control in its turn is influenced both by latitude and by the distribution of land and water, and is further modified by mountain barriers, altitude, prevailing winds, ocean currents, and storms. The relation of land to water is known to have changed many times and with almost incredible slowness throughout the long history of the earth. It is during these times of change that the disappearance of old species and the incoming of new species have been most rapid.

As long as the hawkweed (Hieracium) grows in its normal habitat in the highlands of Switzerland, it remains unchanged; but when transplanted into the lowlands of Munich it develops a different form.

When the eggs of the butterfly *Vanessa urticæ* are hatched in the cold, they give rise to the variety *polaris*, the normal form in Lapland. When they are hatched in a warm place, they produce the variety *ichnusa*, the form normal to Corsica and Sardinia.

The blood temperature of all mammals is inconstant. In children from the second week to the fifth month the daily range is 3.5° or more, before this it is greater, while for many months afterward it continues to vary from one to two degrees. Experiments on the white mouse[1] show that its body temperature could be varied during the first two weeks after birth. When its temperature was reduced during this time, the later-developed adult had tail, foot, and ear shorter than the normal; but when the temperature was increased, these were longer than the normal.

[1] *Journal of Experimental Zoölogy* (1915), Vol. XVIII, pp. 325–432.

It thus appears that tissues are especially sensitive to extremes of heat and cold during a limited period in extreme youth, and that during this time those parts of the body which govern growth may be influenced and varied. In egg-laying animals this time of greater plasticity is during the early growth of the individual within the egg, and immediately after. In mammals it is immediately after birth, since before birth the embryo has the constant temperature of the body of the mother.

Thus we see one reason why glacial periods throughout earth history have been times of rapid evolution. For example, if a glacial climate should again characterize Europe, and if the Mediterranean Sea should prevent a migration southward, the butterfly species cited would produce only the variety *polaris*, and it is probable that in time this variety would become fixed; for, as with habits, long repetition of certain characters appears to make them irreversible, or, as Burbank expressed it, there is no fixity of such species other than through long repetition. Experiments by man apparently cannot be carried on for a sufficiently long time to fix a species so that it will not revert. If, on the other hand, warm temperate conditions should gradually extend to the pole, the variety *polaris* would no longer develop, and the variety *ichnusa* would probably become a fixed species.

Glacial periods of the past. It should be borne in mind that while change in climate is probably the most important single external factor in the production of new species, there are many others which aid their development. Of these, migration and competition are especially important. During the incoming and duration of the last glacial period, that of the Pleistocene, there evolved all the present species of cats, dogs, wolves, bears, squirrels, mice, rabbits, sheep, oxen, deer, camels, horses, monkeys, apes and man. In fact, during this time there evolved nearly all the present species of the warm-blooded animals (the mammals and birds), as well as many reptiles, amphibians, and fish,— especially among the highest

orders of each. Among the arthropods numerous species of insects, spiders, and crustaceans appeared, and among the mollusks, many pelecypods and gastropods.

During this time also very many species of all classes of organisms were exterminated. This disappearance was especially noteworthy among the larger mammals, which included several species of horses, camels, giant sloths, elephants, giant beavers, and the saber-toothed tigers. Because of this glacial period the organic world of today is extremely different from that of the upper Tertiary (Miocene and Pliocene).

The great glacial period preceding the Pleistocene was that of the early Permian, in the closing days of the Paleozoic Era. During the incoming, duration, and disappearance of this glacial period, and the formation of widespread deserts of the later Permian and early Triassic, the large plants and animals so characteristic of the upper Paleozoic disappeared. This period of great climatic changes initiated the notable radiation of the reptiles and brought about metamorphosis among insects. It apparently also fostered a higher and more constant body temperature, thus preparing the way for the mammals and birds of the early Mesozoic. Few, if any, species persisted through this period of stress, though many orders and some genera survived.

Semiaridity. Semiaridity is an evolutionary factor that has always been present somewhere on the earth's surface. Those plastic animals and plants that are sufficiently evolved, and are yet not too specialized to be able to develop an adequate response, survive such a condition. During the Silurian the drying up, in summer, of the pools formed by the spring rains apparently afforded the impetus for the evolution of an accessory lung in the fresh-water fishes and the requisite environment for its selection. The same cause today cannot produce the same result, for in the fish of the present the lung developed by their ancestors of the Silurian has degenerated into a swimming bladder. They are now too specialized to respond in a similar manner to the same conditions.

The development of drought-resisting grasses in the early Cenozoic, and their spread over the drier plains, contributed to the gradual evolution of the swift-footed hoofed mammals. As these ungulates increased in speed, during the millions of years of the Cenozoic, they in turn were a constant stimulus to an increase in cunning and quickness in the carnivores, which again formed an ever-active selective factor contributing to further fleetness in the ungulates.

Character of soil. Chalk forms grassy, bushless hills. The walking fern (*Camptosorus rhizophyllus*) is found only on soil that is very rich in lime; sheep sorrel (*Rumex acetosella*), only where the soil is poor in this substance. A glacial soil, because of its composite make-up, supports a large variety of plants. A geologist who is familiar with plants can trace a decayed igneous dike across the country without the necessity of searching for rock outcrops. A plant which has evolved upon a definite soil now needs for its food and habitat the peculiar substances and physical conditions which characterized that soil. Sandy tracts such as characterize southeastern New Jersey are marked by pine trees, heather, etc. This type of soil selects those plants already developed in similar soils and evolves others suited to it.

Influence of neighboring organisms. Changes may take place in a species in response to the stimulus of the animal or plant life which environs it. The development of plants with an edible bark and with nuts has, since the Mesozoic, acted as a persistent selective factor in the development of chisel-shaped teeth, the principal character of the order of rodents in mammals.

The intrusion of a new species, or the extinction of an old one, may produce marked effects upon the organisms upon which they prey or which they serve as food. Such effects are prominent, for example, in the adaptations which parasitism brings about in both parasite and host (see pages 113–114).

Chemical content of water. Normal marine shells have very little or no epidermis covering the outside, fresh-water shells

have a thick coating, while those from brackish water are usually intermediate. In these cases the carbonic acid, most abundant in fresh water, has been the environmental factor which has brought about the change. Without this acid-resisting epidermis the calcium carbonate shell would soon be dissolved. Thick as it has become, however, in fresh-water shells, wherever the stream is sluggish and filled with much decaying matter (always productive of carbonic acid) the oldest portions of the shells (the tips, or beaks) are eaten through. This brings about death by giving easy access to enemies of various sorts.

ORTHOGENESIS

It often happens that the same changes occur in groups that now live in different habitats and do not interbreed. This is evidence that gradually changing internal factors may continue active for many generations. The Eocene horses evolved similar cusps in the grinding teeth simultaneously in the region of the American Rockies and in Switzerland. From the same primitive dinosaurs arose, during the Mesozoic, the land dinosaur group, Ornithischia, and the flying class, birds. In spite of their very different habitats each of these groups later evolved many similar features, including a tendency toward the reduction in the size of the fore leg (and hence toward the use of only the hind legs in walking) and a trend toward the development of horny beaks and the loss of teeth.

Only through the action of such gradually changing internal factors can overspecialization be explained, — a specialization that is detrimental to the organism possessing it. The tusks of the Columbian elephant, inhabiting North America during the Pleistocene, curved strongly upward and also inward, so that the tips actually crossed each other. They were thus of no use for digging food and were dangerous to the animal itself in fighting, for they could interlock with those of its antagonist. Other examples of overspecialization include the antlers of the extinct Irish deer and the huge horns of the bighorn sheep.

The action of internal secretions. It is well known that various organs of the animal body secrete chemically active products called internal secretions or catalysts. Such a product added to the blood by one organ will, within a minute or two, be quite uniformly diffused throughout the whole body. The action of these secretions is best known in the mammals, especially in man. If the thyroid gland in the neck fails to play its part fully, the growth of the child is arrested, the features become grotesque, and the mind is retarded. Dried thyroid substance from animals, mingled with the child's food, nearly counteracts the defect. When the small pituitary body on the under surface of the brain becomes diseased, there is overgrowth, tending toward the gigantic. The thymus, a mass of tissue high up in the chest, appears also to regulate growth, while the dependence of a symmetrical body and mind upon the normality of the reproductive organs is familiar.

Irreversible differentiation. Orthogenesis due probably to the combined activities of catalysts and nerve growth is seen where the repeated inheritance of some successful change leads to an inability to develop otherwise than in that direction. As a rule, when a plant or an animal once begins to develop in a certain direction, this direction is continued by his descendants ever afterward. The repeated inheritance of a character stabilizes it, and it becomes a hereditary habit. The repeated inheritance of the division of the nervous system and the organs of the body into five radii by some early organisms that gave rise to the echinoderm phylum has compelled all the descendants to continue to evolve in this direction. They subsequently diverged into seven classes, three of which were fixed to the earth and four of which were free-moving, all retaining, however, the basic division of five, although a bilateral symmetry would serve the free forms better than the radial one. Similarly, notwithstanding the very great variation in the spider group, all retain the eight legs impressed upon this line by its ancestry, just as six legs are retained by

all insects in spite of the remarkable variation in their manner of living. The same is true of the four limbs of the vertebrate line from fish to man. In all these groups further evolution was limited to the direction given by the ancestors. We never see a normal four-legged insect, or a six-legged or eight-legged vertebrate.

The pentadactyl limb developed by ancestral vertebrates in the mid-Paleozoic necessitated its inheritance in its descendants, the reptiles, birds, and mammals. The internal skeleton stabilized by the early mid-Paleozoic fish was continued in all later-evolved vertebrate classes, just as the development of the seed by the seed ferns of the mid-Paleozoic made it inevitable that their descendants, the conifers and the flowering plants, should likewise develop seeds. When, by the aid of paleontology, comparative anatomy, embryology, and experimental work, the evolution of animals and plants is carefully observed, it is seen that changes occur in only a comparatively few directions; and the more specialized the organism, the fewer are these directions of possible change.

Because a successful organic change stabilizes the direction of future changes, a line of development once established may lead to far-reaching results. The tubular type of central nervous system evolved by the early vertebrates has continued through all vertebrate classes up to man. This type of nervous system, in correlation with the but slightly modifiable internal skeleton, placed emphasis upon the development of intelligence, as, on the other hand, the organization of arthropods has necessitated in that line the evolution of instinct.

Some early reptiles evolved basal nuclei of gray matter in the cerebral hemispheres. This line advanced to a culmination in the modern birds, in which the basal nuclei (corpora striata) are more massive than in any other animal, and in which the cerebral cortex (the location of intelligence) is very insignificant. Hence it follows that birds present among the higher vertebrates a culmination of instinct, with intelligence of a comparatively low order.

Another line of reptiles, starting with brains somewhat like that of modern turtles, led to the mammalian type with wide lateral ventricles and extensive cerebral cortex. They have thus developed the highest order of intelligence, with a low order of instinct.[1]

TOPICAL REVIEW

Orthoselection:
- Causes of orthoselection —
  - Effects of changing climates;
    - Glacial periods of the past;
    - Semiaridity;
  - Character of soil;
  - Influence of neighboring organisms;
  - Chemical content of water.

Orthogenesis:
- The action of internal secretions;
- Irreversible differentiation.

[1] C. J. Herrick, *Science*, N. S., Vol. 51, pp. 621–625.

V

MAN

A shape looked up from eating herbs and grain,
It chanced to see the stars, and with that look
Came Wonderment and Longing in its train.
The food untasted lay. A beating pain
Smote at its forehead, but it looked again,
And yet again. And then it thought.
Lo! Man stood upright as the stars did wane.

HUGH J. HUGHES

CHAPTER XVI

PHYSICAL EVOLUTION OF MAN

LINE OF ASCENT

Man's physical ancestry begins with the incoming of life upon earth during the Archeozoic Era, over a billion years ago according to the radioactive clock.

From one-celled animals (Protozoa) to primitive many-celled forms (Metazoa) was obviously the first advance. The line through the higher Metazoa includes successively an early representative of the cœlenterates, some segmented form (possibly a worm), and a form embodying the first suggestions of the vertebrate. This earliest representative of animals with a backbone must have possessed a primitive notochord and gill slits, very like the embryos of ascidians. Thence the vertebrate line includes increasingly differentiated classes through forms basically resembling Amphioxus, lampreys, sharks, ganoids, amphibians, reptiles, marsupials, insectivores, lemurs, Old World monkeys, and anthropoid apes up to man (Fig. 20).

EVIDENCES OF ASCENT

There are many evidences that such a succession comprised the human ancestral line.

Comparative anatomy. With some exceptions man's bones, muscles, blood vessels, nerves, digestive organs, etc. are like those of other higher mammals (see pages 57–59). The exceptions become fewer and fewer as we proceed through the insectivores and lemuroids to the anthropoids.

Vestigial organs. In adult man occur many vestiges of organs which are well developed in various mammals below

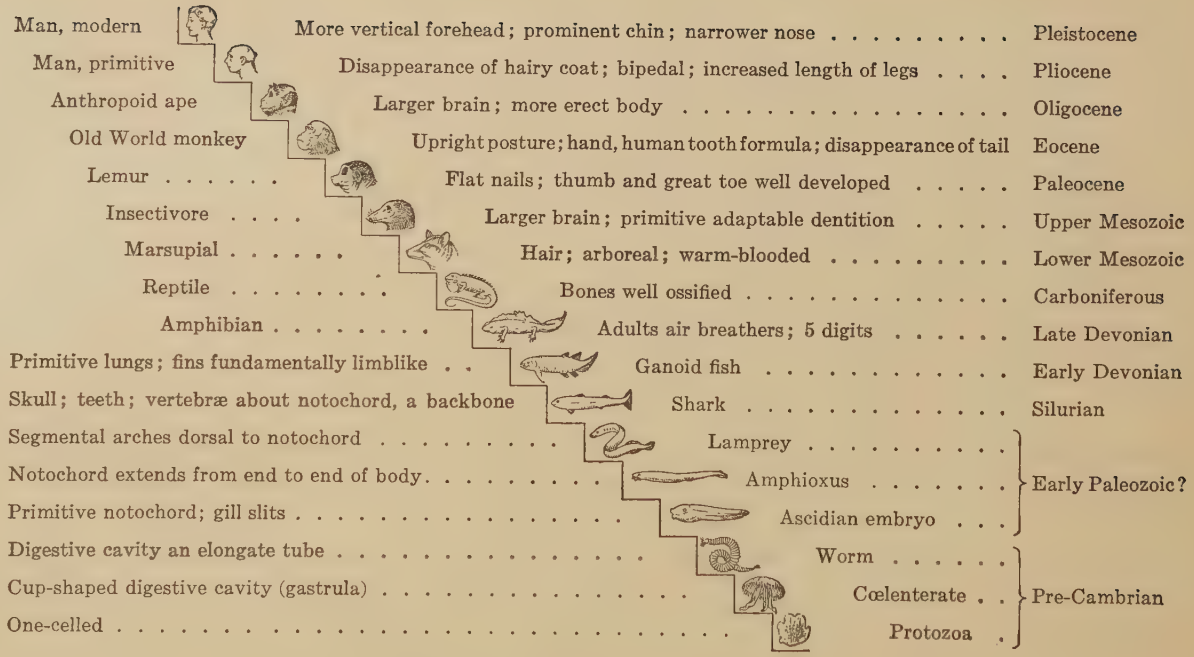

Man, modern
More vertical forehead; prominent chin; narrower nose . . . . . Pleistocene
Man, primitive
Disappearance of hairy coat; bipedal; increased length of legs . . . . Pliocene
Anthropoid ape
Larger brain; more erect body . . . . . Oligocene
Old World monkey
Upright posture; hand, human tooth formula; disappearance of tail Eocene
Lemur . . . . . .
Flat nails; thumb and great toe well developed . . . . . Paleocene
Insectivore . . . .
Larger brain; primitive adaptable dentition . . . . . Upper Mesozoic
Marsupial . . . . . .
Hair; arboreal; warm-blooded . . . . . Lower Mesozoic
Reptile . . . . . .
Bones well ossified . . . . . Carboniferous
Amphibian . . . . . .
Adults air breathers; 5 digits . . . . . Late Devonian
Primitive lungs; fins fundamentally limblike . .
Ganoid fish . . . . . Early Devonian
Skull; teeth; vertebræ about notochord, a backbone
Shark . . . . . Silurian
Segmental arches dorsal to notochord . . . . . .
Lamprey . . . . . .
Notochord extends from end to end of body. . . . . .
Amphioxus . . . . . Early Paleozoic?
Primitive notochord; gill slits . . . . . .
Ascidian embryo . . .
Digestive cavity an elongate tube . . . . . .
Worm . . . . . .
Cup-shaped digestive cavity (gastrula) . . . . . .
Cœlenterate . . Pre-Cambrian
One-celled . . . . . .
Protozoa .

Fig. 20. Steps in man's evolution

him. Wiedersheim discusses many of these in his "Structure of Man." Man possesses remnants of skin-twitching muscles. These are well seen in the forehead and to a less degree on the scalp. They are most functional in the face, where they are used for the expression of emotions. Remnants of ear-twitching muscles are sufficiently preserved in some men to enable them to move the ear very noticeably; these muscles are also vestigial in the chimpanzee and orang-utan. At the inner corner of the eye is a small fold (*plica semilunaris*) which is a vestige of the third eyelid, — the nictitating membrane of many mammals and of birds. This fold is larger in negroes and the ancient Australians than in the whites.

Another well-known vestigial organ is the vermiform appendix, present also in the anthropoid apes. In reptiles, birds, and mammals there is a strong tendency to form one or more blind pouches (*cæca*) at the junction of the small and large intestines as an aid in digestion. In mammals a single cæcum is developed. This, rudimentary in the insectivores, becomes very long in the herbivores but vestigial in the primates. In the embryo of man the cæcum has at first the same diameter throughout, but later the tip ceases to grow and becomes the appendix.

Thus we see that man's body contains many organs so far on the down grade that they are as Osborn says "mere pensioners of the body, drawing pay (that is, nutrition) for past honorable services without performing any corresponding work."

Progressive organs. Just as the human body bears within itself vestiges of organs which were of great functional value in various ancestors, so it possesses organs which are tending toward more perfect adaptation. Such are the increasingly efficient muscles of the hand, the fingers, and especially the thumb, the arch of the foot, the great toe, the projectile nose, the well-developed outer layer of gray matter of the brain accompanying increasing intelligence, and the more subtle differentiated muscles of the larynx associated with articulate speech.

Ontogeny. From the fertilized one-celled ovum to adulthood each human individual passes through successive stages basically similar to the forms listed under Line of Ascent (p. 139). Many of these stages can hardly be distinguished from corresponding developmental stages in other animals.

Earliest stages. Every animal begins its life as an organism consisting of a single cell. Some, the Protozoa, remain throughout their entire lives as independent cells or colonies of cells. All other animals, the Metazoa, develop, through the subdivisions of this initiatory single cell, into a many-celled adult in which the cells are interdependent.

The first great step in the evolution of the Metazoa was the transformation of a protozoan colony of similar one-celled organisms into a single organism of many interdependent cells. The second great step was the down-sinking of the cells of this somewhat globular organism at one definite point, resulting in the formation of a cup, the gastrula, consisting of two layers of cells. Since, from this point on, the outer layer of cells, the ectoderm, must protect the organism and receive external stimuli, certain of these cells became more sensitive and elongate, constituting the nervous system, while others developed an external protective skeleton. At the same time the inner layer of cells, the endoderm, specializing in the digestion and assimilation of food, developed into the digestive cavity and its accessory organs. Each human being during his embryonic development passes through these stages. He is first a single cell. This, through repeated subdivision and the later inpushing of one wall, becomes a gastrula.

Digestive system, including teeth. In such lowly forms as the cœlenterates (corals, jellyfish), which remain throughout their lives in the gastrula stage, the digestive cavity continues to be large and cup-shaped, but in the higher animals it becomes restricted in size. In the development of the vertebrates the primitive gastral opening closes, while a new mouth and anal opening are formed at opposite ends of the body by the inbending of the ectoderm and its rupture at its inner ends.

Thus in the vertebrates (and in the arthropods) the alimentary canal consists of two outer portions, formed of ectoderm, and an inner part, the real digestive tract, formed from endodermal cells. It has thus come about that such products for external protection as chitin in the arthropods and calcium phosphate scales in the vertebrates are utilized in the anterior portion of the alimentary canal for the tearing and grinding of food. The fish had early developed an external protection of hard, posteriorly pointing bodies, variable in size and shape, known as placoid scales. These are composed of dentine covered above with enamel and at the base with a bonelike cement. The vertebrate mouth came thus to be coated with such placoid scales. (In some present-day fish the body scales pass insensibly into the teeth over the ridges of the jaws and agree with them in structure and in embryonic history.) These placoid scales, acting as teeth, were so perfectly fitted to the varying purposes to which they have been put that they have continued to be inherited in all vertebrate classes, though with endless changes in form, arrangement, and number. Even in man the teeth still consist of dentine capped with enamel and surrounded below with cement, while their embryonic development is similar to that of the placoid scales.

Kidneys. In man, in a very early embryonic stage, the liquid waste is taken care of by a primitive sort of kidney (pronephros) located in the neck region; later this is replaced by a second kidney (mesonephros), and finally the true kidney (metanephros) replaces the second and continues to function throughout life. In Amphioxus and the lamprey the pronephros is alone present; in the fish both the pronephros and the mesonephros are functional in the adult. In frogs and toads the pronephros degenerates, and only the mesonephros persists. In reptiles, birds, and mammals, as in man, both the pronephros and mesonephros are present and functional only in the embryo, being replaced by the true kidney (metanephros), which alone is functional in the adult.

Gill slits; gill arches. In vertebrates, as well as in the more primitive chordates, the Urochorda and Adelochorda, the respiratory function is located near the anterior end of the digestive canal. Here openings were developed in the lateral walls of the canal, which were at this point richly supplied with minute blood vessels through which the interchange of the waste gases of the body and the free oxygen of the water could take place. In the lower vertebrates the lining of these walls grows out into folds, the gills. Water is drawn in through the mouth and driven out through these openings, the gill slits. Each gill slit is separated from its neighbor by a supporting rod of cartilage developed in the body wall. These supports constitute the gill arches.

This general respiratory pattern is the permanent adult condition in those animals that continue through life to breathe by means of gills. Fish possess a series of gill slits on each side of the neck through which the water used for respiration passes out. In the lamprey there are seven; in the shark (Carcharias), five. Since these branchial clefts are useless in air breathers, however, they are transitory, present only in the embryo, or youthful stage. In birds, mammals, and man only four gill slits arise; these are usually closed by a thin membrane, and hence never actually function as a respiratory apparatus. They appear in the chick during the third day of incubation, and in the human embryo when it has reached a length of from three to four millimeters.

At the same time that gill arches are present in the embryos of air breathers, the heart is fishlike. It is placed far forward and has passed from the earlier tubelike stage of Amphioxus, and is now divided into two chambers. Later it is pushed back between the developing lungs and gradually acquires three cavities, distinctive of Amphibia; finally, in birds and mammals, it develops the complete double circulation through four cavities.

Lungs; larynx. In the primitive fish of the Paleozoic there was a tendency for the anterior portion (pharynx) of the ali-

mentary canal to develop outpocketings (diverticula). Such air bladders increased the buoyancy of the fish and were thus an aid to swimming. In Polypterus, one of the two surviving most primitive ganoid fish, this outpocketing is ventral in position, thus corresponding to the position of the larynx in the embryo of higher vertebrates. This single outpocketing in Polypterus is divided into two branches, thus forming paired lungs. In their further subdividing in the higher vertebrates these lungs usually become more complicated.

In the amphibians the fifth pair of gill arches, with their muscles, become modified into a very effective larynx (voice box) within which mucous folds arise which are the vocal cords. In the higher vertebrates, muscles become attached to the ends of these folds, the expansions and contractions of which give rise to variations in the pitch of the voice.

Endoskeleton. The vertebrate endoskeleton consists primarily of three distinct systems, — the axial (backbone and head), the visceral (jaws, hyoid, etc.), and the appendicular (limbs with their supports).

1. *Axial skeleton.* The oldest of these three systems is the axial. This is represented at first by the notochord, a cylindrical rod of semigelatinous tissue extending through the longitudinal axis of the body. It is surrounded by a sheath of connective tissue which is produced above so as to form a cylinder about the nervous system, — the spinal cord. In this condition it is present in the adult Amphioxus but also appears in the early embryonic life of all higher vertebrates.

The next stage, which is retained in the adult cyclostome, the lamprey, is the growth of segmental cartilaginous arches (neural arches) upward on each side of the spinal nerve cord. These are developed from the sheath inclosing the notochord. The succeeding stage appears in the adult sharks (dogfish etc.). In this stage each neural arch forms a ring about the spinal cord, while beneath each arch the connective tissue develops a cartilaginous ring (vertebra) about the notochord. Thus the notochord becomes constricted in the median line

of each vertebra. Each vertebra is consequently biconcave with a hole through the center through which passes the remnant of the notochord. In the higher vertebrates these more or less cartilaginous vertebræ increase in size until, in the adult, the notochord entirely disappears. At the same time the cartilage becomes entirely replaced by bone. In all the higher vertebrates, including man, this transition from notochord to cartilaginous vertebræ and neural arches, and then to bony ones, is repeated in the embryo.

The embryonic history of the skull of man, as of all other vertebrates, shows it to be formed primarily of two elements, the primordial skull and the dermal bones. The former was developed at the anterior end of the notochord, — the strengthening rod preceding the backbone. It was apparently evolved as a support to the brain, since it developed at the sides of and partly beneath the brain. In the embryo the primordial skull is at first composed of cartilage, and since the selachians (sharks) do not pass beyond this stage, it is called the selachian stage. It is passed through by all the higher vertebrates.

The succeeding embryonic stage is also fortunately preserved as the adult state in the few surviving ganoid fish (example, sturgeon) and is hence known as the ganoid stage. In this the primordial cartilaginous skull is replaced by bone, while external dermal plates of bone surround it on all sides. The dorsal side of the brain is now fully protected. These dermal bones, a definitely arranged series of large plates, were formed by the fusion of the basal pieces of many placoid scales. In the higher vertebrates, while some of these are lost, the others, becoming covered with skin, unite with the primordial skull. This state is first seen in the adult amphibian. Of these dermal bones man still retains many, such as the frontals, parietals, squamosals, and nasals among those dorsally placed, and the palatines, pterygoids, and parasphenoids among those at the base of the skull, that is, at the roof of the mouth.

2. *Visceral skeleton.* In all vertebrates from the sharks up, the most anterior pair of the gill arches develops into the upper and lower jaws of the adult; that is, this first pair of gill arches divides into a dorsal and a ventral portion. It retains this primitive condition in the adult shark, but, progressively in the ganoid fish, amphibians, reptiles, and mammals, it gradually becomes covered and replaced with dermal bones.

From the first gill slit, the opening posterior to the arch forming the jaws, is developed the tube leading to the inner

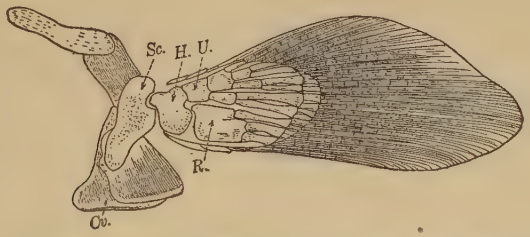


Fig. 21. Pectoral fin of a crossopterygian fish (*Sauripterus*, from the Devonian)

Cv., clavicle; *H.*, humerus; *R.*, radius; *Sc.*, scapula; *U.*, ulna. In man the clavicle is the collar bone; the scapula, the shoulder blade; the humerus, the upper-arm bone; the radius and ulna, the bones of the forearm. (After W. K. Gregory)

ear. From outgrowths upon the first and second arches around this opening arose the part of the ear which projects from the sides of the head.

The cartilaginous rod of the second gill arch forms the hyoid bone. In adult fish the most anterior gill-bearing arch is the third.

3. *Appendicular skeleton.* The limbs of terrestrial animals apparently have their origin in the pectoral and pelvic fins of such mid-Paleozoic primitive ganoid fishes as the crossopterygians. The fins of these ancient fish were basically limb-like (Fig. 21). This is especially true of the pectoral fin, in which occur, in proper sequence, the principal bones of the vertebrate fore limb, — the clavicle and scapula (the latter with a cavity into which fits the rounded projection of the

humerus) and, attached to the distal end of this, the radius and ulna. Beyond these are some that correspond partly to the bones of the wrist and fingers.

Immediately above the fish, that is, with the assumption of a terrestrial life by the amphibians, the wrist consists of a series of small bones from which radiate five digits, each composed of several bones. The same is here true of the hind limbs. That is, by the development of the amphibians there had been evolved shoulder and hip bones to attach the limbs to the body, in each of which is a socket to hold the head of the single upper-limb bone, followed below, in succession, by two lower-limb bones, a series of wrist or ankle bones, and then five digits. This arrangement of bones holds true of all higher vertebrates, — the amphibians, reptiles, birds, and mammals, — except where one or more are subsequently lost (see Fig. 7).

By a gradual increase in the size and strength of the limbs the animal changes from a crawl to a true walk; that is, the body becomes lifted free of the ground. Since the hind limbs sustain the greater amount of the weight of the body, the hip bones become solidly attached to the backbone.

There is an evolution of organs of progression from lower to higher animals. The protozoan Amœba moves by means of merely temporary projections of its body. The marine worm Nereis has a series of short paddles on each side of its elongate body. The fish possesses fins. All these are buoyed up by the water. In land animals the limbs must lift as well as give progression. In these there is a gradual reduction in the number of props in the higher forms. The myriapod has a score or more of legs, the insect six, and the vertebrate four. The next stage is the tipping of the body and balancing it upon two legs. This was accomplished by a number of genera of dinosaurs in the Mesozoic, but in their case it was accompanied simply with reduction in the size of the fore limbs. In the birds the fore limbs were transformed into wings. In man they became hands (tool users), by means

of which he enlarges his control of nature. The simple freeing of the fore limbs from the necessity of walking was not sufficient; it had to be accompanied by a mentality capable of utilizing them to progressively higher ends.

Summary. It is seen that the human body represents a battle-scarred makeshift in which highly modified organs subserve purposes very different from their original or former uses. Man's teeth have developed from external scales, while from the union of the bony bases of such scales, later covered with skin, developed the bones protecting the brain. His heart evolved from an ordinary blood vessel; his larynx, and hence the basis of his speech, from a pair of gill arches no longer needed for their original purpose. The basic parts of his upper and lower jaws are the modified first pair of gill arches, while the gill slit posterior to this has become the tube conveying sound to the inner ear. His limbs are adaptively modified fins, while his lungs have evolved from an outpocketing of the pharynx developed by fish to increase their buoyancy. As Darwin has said, "man still bears in his bodily frame the indelible stamp of his lowly origin." In his various organs of support, protection, digestion, assimilation, respiration, there is no detail of structure which does not owe its characteristics to a long ancestral line of evolutionary adaptations.

Comparison of primates. There are many ontogenic characteristics indicating the close relationship among the various groups of primates.

The milk teeth of man are basically identical with the milk teeth of the anthropoid apes. The formula for the milk teeth — two incisors above and below on each side, one canine, and two premolars — is the same in all human races, all anthropoid apes, and all Old World monkeys.

Adult man has eyes close together, an arrangement which gives him parallel vision, the highest type yet evolved; but in the embryos of all primates the eyes are as far apart as in the adults of the carnivorous mammals. The nine-weeks

human fetus has a width between the eyes of more than half the width of the face. This gradually lessens to less than one fourth the width of the face in the adult white. In the Tasmanians and Hottentots the eyes are relatively farther apart than in the more advanced human races.

The face (that is, from the tip of the chin up to the junction of the nose and forehead) enlarges faster than the forehead in all primates during fetal growth, and this enlargement is continued to adulthood.

The human nose becomes relatively higher and narrower from the early fetus to adulthood. The nose of the young child is intermediate in height and breadth between that of the fetus and that of the adult. This change is greater in the white than in the negro. In the adult ape the nose is similar to that of the early human fetus.

In the human fetus the collar bones project upward. This position is retained in adult monkeys and apes. In adult whites it descends to the horizontal, and to a less degree in primitive human races.

The relative length of arm and leg changes during the growth of the fetus and later. In man at the beginning of fetal development the length of the arm is much greater than that of the leg. This proportion changes until at about one month after birth arm and leg are of equal length. The comparatively great length of the leg in adult man is thus entirely due to growth after birth. Relatively long arms and short legs are decidedly simian characteristics. Among men today there are frequent examples of retardation in one or more of these characters, with otherwise normal development, — physical, mental, and moral.

In the primates the hand and foot become relatively narrower with advancing age. Of all the primates, man and the gorilla have the broadest hands and thus retain the fetal condition to a greater extent than do the others.

The power of grip of the human babe is remarkable. In less than an hour after birth it is able to sustain the entire

weight of its body for at least ten seconds by clinging to a finger or small stick. When thus clinging, it never cries until its grasp begins to give way. Its strength increases to a maximum in about three weeks, when it can hang thus for a minute or two. Always, when thus suspended, its thighs are bent nearly at right angles to the body. This grasping power of hands and legs also characterizes the young of the anthropoid apes.

In the embryos of all higher primates the soles of the feet face inward. In the course of growth they bend more outward. Adult apes still place the lateral edge of the foot to the ground. At birth man also places his foot thus and this remains a restful position all through childhood; even adults find it a restful position, especially when sitting. This, as well as the remarkable grip of the babe, can be explained most logically as due to an ancestral tree-dwelling existence.

The great toe in the embryos of man, the ape, and the monkey is similar, being much shorter than the second and projecting at a strong angle from the other toes, much like the thumb in adult man. In man the great toe, even at birth, still forms a noticeable angle with the other toes. Similarly, in all primate embryos the middle toe is longest; it remains so in adult apes and monkeys, but in man it is superseded in length by the second toe and usually still later by the great toe.

The embryo of all primates possesses a tail projecting much beyond the rudimentary legs, just as is the case in all other vertebrates. On the under side of this embryonic tail there occurs a series of V-shaped bones (chevron bones) such as are characteristic of many other mammals. These and the tail are normally resorbed by the growing embryo in apes and man. At times, however, the tail persists even in the adult of the normally tailless chimpanzee, orang-utan, and man.

The surface of the human fetus up to the seventh month is covered, with the exception of the lips, palms, and soles, with

long, dark hair. This is the lanugo, which with rare exceptions disappears before birth. A similar hairy coat is also found on the embryo of such hairless mammals as the elephant and whale. It seems to represent the hairy coat of the adults of other mammals. Its absence in man, as in the elephant, whale, hippopotamus, and other almost hairless mammals, is due to some unknown internal factor tending to develop a more or less hairless condition. Among other causes in man's environment tending to select the less hairy individuals is the more hygienic character of greater hairlessness for a life within shelters and with clothes. Because of the greater activities of such parasites as those producing skin disease where the body was covered with thick hair, natural selection would favor the less hairy individuals.

These and many other resemblances between man, the ape, and the monkey in their embryonic development, and the frequent close correspondence between their subsequent growth stages, can be best explained by assuming a common origin for all. Common tendencies of development inherited by these groups from the same ancestors became modified through later-acquired divergent habits. This divergence of the common ancestral stock into apes and man began a long time ago, — long enough to permit of the vast changes which we now see between the adults of these two groups. In the direction of the collar bones, the relative length of arms and legs, the shape and size of hands, fingers, feet, and toes, the hairy coat, the uprightness of position, the curvature of the backbone, and many other characters the great length of time is indicated.

Compared with their own young the adult apes show a degeneracy in such characters as reduced forehead and increased massiveness of the lower jaw. In the gorilla, for example, from the fetus to adulthood the brain case becomes relatively smaller, the face protrudes more and more, while the nose becomes less and less prominent during growth after birth to adulthood. On the other hand, adult man, compared

with his own young, shows an increase in the size of his brain case, a more distinct forehead, and a decrease in the massiveness of the lower jaw.

SUMMARY OF MAN'S EVOLUTION

Man inherits his body from prehuman ancestors. Bone for bone, the plan of the skeletons of man and all other mammals — horse, cat, dog, elephant — is identical. So, too, with all other bodily organs. More than four hundred of the muscles moving man's body are present also in the cat, ending in the same bones, controlled by the same nerves, and having similar functions. And thus it is with all the mammals. Just as similarity of word form and of construction in French, Italian, and Spanish indicates a common ancestry, or the number five in the starfish, sea urchin, sea lily, and other classes of echinoderms points to a common ancestor, so the unity of structural plan in mammals indicates a common ancestry for them.

Not only, however, is man related by blood to all the mammals; he is more distantly akin to all animals with a backbone, for all — primitive fish, amphibian, reptile, bird, and mammal — are built upon an exactly similar plan. All possess a backbone expanded anteriorly into the skull, through which extends the central nervous system sending off similar nerves to all parts of the body. This stiffening and supporting rod, the backbone, has attached to it two pairs of limbs with similar hip-bone and shoulder supports. Man is still more distantly related to the animals without a backbone, — the jointed worms, the jellyfish, and the microscopic one-celled protozoan Amœba. The relationship is likewise displayed in the individual life histories of all the higher animals, including man. Each begins life as a minute protozoan-like cell, which develops into the ground plan of a jellyfish (the gastrula), and this into an elongate form basically similar to the jointed worm. Thence the development proceeds through a

form with gill arches and other characters of the fish, and thus by innumerable steps to man as he appears at birth. The human brain shows during its development a similar relationship to lower vertebrates. In a very young embryo it basically resembles the brain of an adult fish, later of such a primitive mammal as the marsupial, and still later that of such higher mammals as the lemurs.

The evidence from embryology is corroborated by the chemistry of the blood. A chemical test has long been used in law courts in murder cases. In this test the amount of precipitin formed identifies the animal whose blood is used, and the amount of precipitin formed is increasingly less in proportion to the decreasing degree of relationship. Chimpanzee blood gives 90 per cent as much as man himself, the lower monkeys one fourth or one third as much, the lower mammals much less, and thus downward in the scale. The same relationship is shown by the crystals formed from oxyhemoglobin present in arterial blood.

That this succession of animals indicates the steps in man's evolution is likewise indicated by the fact that these forms succeed one another in earth history (Fig. 20). The protozoan, jellyfish, and worm were present upon earth during the very ancient Proterozoic time; the fish appeared first during the lower Paleozoic, the amphibian in the middle, and the reptile during the upper Paleozoic. The earliest mammal made its appearance in the early Mesozoic, and 'man in the later Cenozoic. Evolved at various times during earth history, they persisted because of various factors of survival value which were passed on through inheritance to succeeding generations. Thus it is that man has inherited, in various stages of advance and degeneration, the organs of his body evolved by these various ancestral organisms. All these bodily organs, the progressive hand and brain as well as the vestigial wisdom teeth and appendix, are factors which enter into man's life.

TOPICAL REVIEW

Line of ascent.
Evidences of ascent:
- Comparative anatomy;
  - Vestigial organs;
  - Progressive organs;
- Ontogeny;
  - Earliest stages;
  - Digestive system, including teeth;
  - Kidneys;
  - Gill slits and gill arches;
  - Lungs and larynx;
  - Endoskeleton;
    - Axial (notochord-backbone and skull);
    - Visceral (jaws etc.);
    - Appendicular (limbs);
- Summary;
- Comparison of primates.

Summary of man's evolution.

CHAPTER XVII

PRIMATE ANCESTORS OF MAN

Arboreal life. The most important single step in the physical evolution of man was the development of an arboreal life by his pre-primate ancestors, and its continuance by the early primates. To this step man owes his hand, which in its offensive and defensive possibilities largely supplanted the earlier use of the teeth. Life in the trees likewise fostered agility and quickness of decision. This was of necessity accompanied by an increased development of the brain, which brought as an accompanying corollary an increasingly upright posture; for, as the cerebrum bulged upward, backward, and downward to accommodate itself to the rounded skull, the posterior part of the brain, the medulla, became bent more and more at right angles to the base of the brain (Fig. 9). In the fish and reptile the direction of vision, the base of the medulla, and the spinal cord are in a horizontal line. In the bird and mammal the medulla has been pushed downward so that it forms an angle of about 45° to the line of vision and the base of the brain, while in man it is at 90°, that is, at right angles to the base of the brain instead of in a line with it. In monkeys the position is intermediate between man and such mammals as the horse and dog. The commoner New World tailed monkeys, the Cebidæ, must throw back the head to look forward,— a position which they cannot long hold without tiring. Hence they adopt the more restful upright posture when sitting, but cannot yet walk upon their hind legs. In the anthropoid apes the medulla is pushed still more toward the vertical, which brings the eyes still farther beneath, so that, if the animal walks on all fours, the eyes look directly into the ground. They hence prefer an erect atti-

tude to the great bending of the neck, and this erect attitude man has inherited. As a result of continued variation and natural selection along the line of an erect posture the fore limbs have shortened and the hind limbs have lengthened and straightened, the great toe has lost its opposability and is used as an added support for the weight of the body, a sigmoid curve has developed in the backbone in response to the need for balancing upon two instead of upon four supports, and the hands, entirely free from their earlier use for walking or climbing, are used for examining objects and handling tools. Upon their use man builds his higher education. It is of interest to note that modern educational methods recognize the value of the training of the brain through the hand.

Lemuroid ancestors. Since the earliest known evidences of the presence of man occur in sediment deposited during the Pliocene, it is obvious that the human family must have branched from some anthropoid stock during an earlier period, probably the Miocene or upper Oligocene. These ancestors, in turn, were a derivation from a primitive lemuroid stock, probably in the Paleocene, since generalized lemurs in several extinct families, such as the Notharctidæ and Anaptomorphidæ (both truly arboreal, as shown by foot structure), occur in the early Eocene of North America. In the Paleocene are found very generalized forms (like Indrodon) variously assigned to the lemurs and insectivores (Fig. 22).

It is thus apparent that the primitive lemuroids arose from a tree-dwelling, generalized insectivore of the Upper Cretaceous and in turn gave rise to the highly specialized lemurs of today and to the primitive Anthropoidea.

Early anthropoids. The early ancestral anthropoids were probably somewhat comparable to the primitive Notharctidæ and the shorter-skulled and more anthropoid-like Anaptomorphidæ. In summing up the latter family Scott, in "A History of Land Mammals in the Western Hemisphere," says: "It is hardly likely that these American lemurs were the

actual ancestors of the anthropoids, but they closely represent what those ancestors must have been."

The Anthropoidea include the Old World and New World monkeys, the higher apes, and man. The New World monkeys (Platyrrhines) have well-developed and prehensile tails, nostril openings directed outward and separated by a broad cartilage, and the following tooth formula: in each half of each jaw, incisors, 2; canines, 1; premolars, 3; molars, 2. In the Old World monkeys (Catarrhines) a tail may be present or absent, but is not prehensile; the nostril openings are directed downward and are close together; and the tooth formula is incisors, 2; canines, 1; premolars, 2; molars, 3. Since both man and the anthropoid apes possess these characters of the Old World monkey, it is apparent that these three groups share the same ancestors (the New World monkeys may represent an earlier offshoot of the same primitive stock). The present-day monkeys, specialized during the subsequent millions of years to a tree life in warm regions, can give but a general idea of what these more intelligent, more progressive, more generalized ancestors of the Old World monkeys, apes, and man were like. H. F. Osborn[1] has suggested that man did not pass through a primitive stock which held only the ancestors of man and those of the apes, — that the human line branched off from the earlier Anthropoidea instead of from the primitive large anthropoids (see Fig. 22).

Large anthropoid stock. That every bone of the skeleton of man, nearly all his muscles, the arrangement of the viscera, the placenta, and many other characters are fundamentally identical with those of the arboreal apes seems to indicate that the higher primates must have had a common ancestry.

Ontogeny points to the same conclusion. The differences between the bodily proportions of man and of the apes increase with advancing growth from early fetal stages (that is, the fifth or sixth week of embryonic life) to the mature adult. In the early fetus of both groups the arms are much longer

[1] *Science*, N. S., Vol. 65, pp. 481–488.

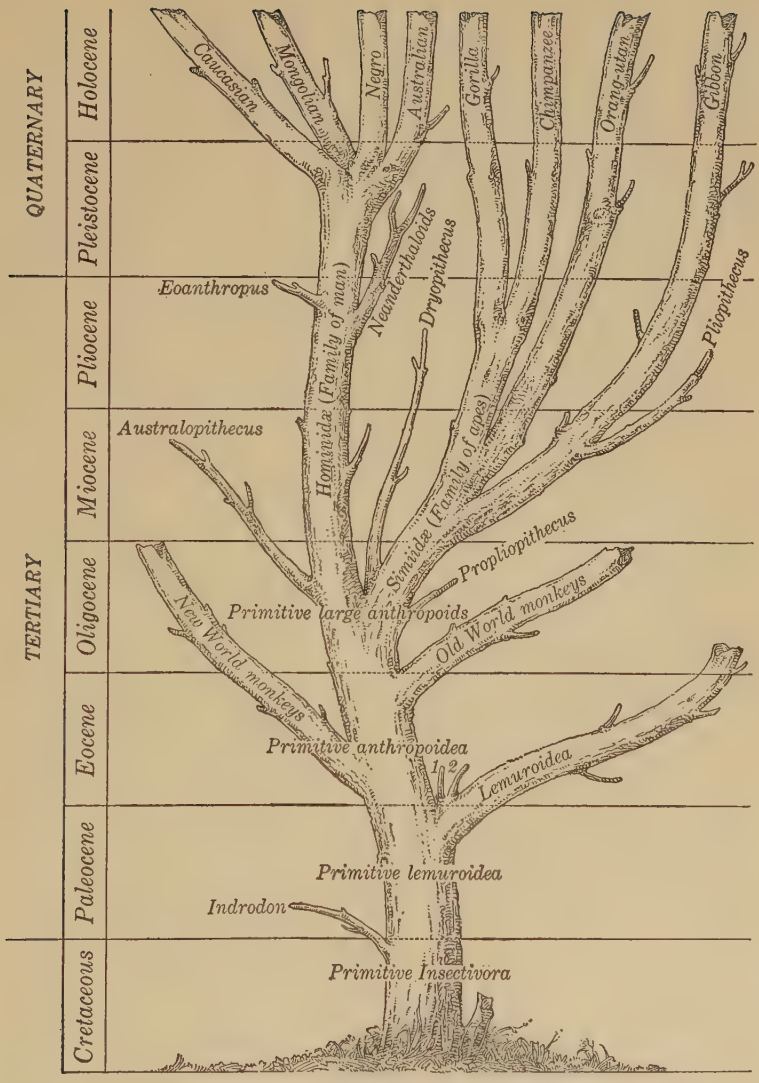


Fig. 22. Evolution of the primates

than the legs. In the apes this proportion is in general retained to adulthood; in the human line the legs lengthen greatly in proportion to the arms. From a similar early condition of thumb and hand in apes and man the apes have developed the hand into a hooklike grasping organ, with consequent degeneration of the thumb, while man has retained the broad hand and developed the thumb into a tool-making instrument. From a similar type of fetal foot man has developed a bipedal habit, with a walking and running type of foot and great toe, while the apes have retained the quadrupedal habit when on the ground. In walking, the adult gorilla and chimpanzee so place their hands that the outer surface of the middle segments of the fingers touch the ground, with the consequent development of a callus. The young ape skull has a more distinct forehead than has the adult, while the simple brain convolutions of a human child approach those of the ape. Thus the man line has diverged from the common stock in the direction of progressive intelligence and the consequent rapid development of the fore-brain, while in the ape line there has been arrested intelligence and brain development.

The primitive foot, typical of the mammals, has a centrally located leverage axis, as is seen in the opossum, pig, deer, and dog. Only in man and the higher apes does it lie along the inner border of the foot, along the line of the great toe. This is due to the inward slant of the joint surface of the heel bone, upon which rests the ankle bone, which in turn supports the weight of the body. Apparently it is only an arboreal life that could cause this displacement. In such a life the weight is thrown upon the outer edge of the foot as the foot clings by means of the great toe to the side of a branch. This stage is repeated in the inward flexure of the foot in the newborn child. The slant of the joint surface is greatest in the anthropoid apes (a retention due to their arboreal life), is much less pronounced in the Neanderthal men of the Pleistocene, and is least pronounced in modern man. The arching of the human

foot is the outcome of a remodeling of the bones so as to produce a balanced posture.[1]

The extinct genus Dryopithecus includes some of the fossil forms which stand nearest to the ancestral large anthropoid stock. These are probably to be classified as early true apes, though they may possibly belong to the generalized line before divergence occurred, since some of the species are related more closely to the chimpanzee and gorilla and others are related more closely to man. They were as large as a chimpanzee, and the canine teeth were human in their relatively small size, not fanglike, as in adult modern apes. The molar teeth show a similar ancestral character. According to W. K. Gregory[2] the peculiar arrangement of cusps and grooves characteristic of the grinding surface of the lower molar teeth of Dryopithecus was foreshadowed in the very primitive, gibbonlike Propliopithecus of the lower Oligocene of Egypt. Among men this type of molar tooth is least modified in the upper Pliocene man of Piltdown. It is retained in the youths of the Pleistocene races, but becomes obscured in the adults. The modern adult apes have retained this pattern with diverse slight modifications, while adult modern man has departed from it most widely.

What appears to be a late representative of the ancestral stock, but on the human line, is Australopithecus. This very primitive manlike anthropoid is known by the skull and fragments of the arms of an immature individual. It was found at Taungs, in Bechuanaland, South Africa (roughly in the latitude of Johannesburg). This region is arid and has apparently been so since early Tertiary times. Such a region could not be traversed by any of the semiarboreal anthropoids of Africa. Life here would accordingly indicate that the group to which the young anthropoid belonged had attained a degree of physical and psychical advancement that had separated it irrevocably from its tropical cousins. Such divergence is further

[1] D. J. Morton in *Natural History*, Vol. XXVI, pp. 310–314.
[2] In *Natural History*, Vol. XXVI, pp. 300–309.

emphasized by the character of the head. It lacks the marked eyebrow ridges, the jutting forward of the muzzle, and the falling back of the forehead which are characteristic of the living anthropoid apes. In these respects this young individual approaches man. The brain capacity of an adult of this species (estimated at 625 cubic centimeters) also lies midway between that of the chimpanzee (400 cubic centimeters) and the early man Pithecanthropus (940 cubic centimeters). The age of the limestone embedding this fossil is indeterminate, but a general middle to late Tertiary Age is indicated by the general geology, physiography, and associated animal remains.[1]

If we consider the comparative anatomy, ontogeny, fossil forms, and present habitat of their descendants, we conclude that the apes, the more conservative branch of the primitive large anthropoids, became confined to the more tropical forests and here gradually evolved into the apes of today, degenerate from their more advanced ancestors but especially adapted to their present mode of life. The more progressive branch of the same primitive stock, with innate variation toward longer, more cursorial legs, a more adaptable thumb, and progressive intelligence, adapted themselves to the more varied life upon the ground and evolved finally into present-day man.

Thus innate variation and environment were important in the development of man. Innate variation enabled some early mammals to take to an arboreal life and developed the many changes resulting in man, while the external factor of natural selection preserved such variations as were suited to the particular environment. Other variations were probably due to the action of the endocrine glands — interstitial, pituitary, pineal, thyroid, suprarenal. These glands, evolved by various early ancestral animals and inherited by the primates, secrete chemical products (hormones) which initiate particular changes in various parts of the body.

Environment for the development of man. Since the fossil forms of New World monkeys, thus far found, are confined to

[1] Raymond Dart in *Natural History*, Vol. XXVI, pp. 315–327.

the New World, and those of the Old World monkeys to the Old World, it is probable that the early stock which gave rise to the anthropoid apes and to man developed in the Old World. In that hemisphere central Asia has at present the highest claims to being the ancestral land. It is sufficiently large to enable the evolution of several distinct species to take place. Moreover, the climatic conditions in the Oligocene and Miocene were such as to encourage the descent from the trees of the human branch of the ancient stock.

The necessary external urge for the change from an arboreal to a terrestrial mode of existence may have been the slow, progressive elevation of some large forested region, with a consequent increasing aridity in places. Such a region was central Asia during Tertiary times. During the early Tertiary it was covered with luxuriant semitropical forests. By mid-Tertiary the forests were of more northern character and were interspersed with more open plains. The more open spaces would tempt early man into exploratory trips upon the ground and would lead him to rely less upon the protection of the trees.

As man expanded his possibilities such an environment would prove so diversified as to make the struggle for existence severe; it would tax his resourceful and inventive faculties, increase his strength of limb in long journeys and his strength of lungs in running, and develop quick vision and stealth in the chase. The region would be cold enough to lead to the early use of fire for warmth, and thus to the preparation of food and to the crude beginnings of architecture in the construction of shelters. (When, much later, man migrated to regions where, as in Europe, the extreme cold of Pleistocene glaciers invaded his realm, he took to a temporary life in caves.)

Diet of early man. A life upon the ground in such a region of vast open plains diversified with rivers and forests would change the diet to include more animal food. Until man began agriculture he could not find sufficient vegetable food

in such a region, and the procuring of game thus became necessary to his continued existence. That some of the animals thus utilized were wild cattle of the plains, the pigs of the forests, and the fish of the streams is shown by the many parasites which they possess in common with man of today. The pork tapeworm is confined to man and pigs, the beef tapeworm to man and cattle, the fish tapeworm to man and certain fresh-water fishes. Since these tapeworms do not appear to be readily adaptable to other hosts, it is apparent that man has been eating these foods through the long ages needed for the tapeworms to adapt themselves to their present restricted habitat (see page 112).

That early man utilized a variety of vegetable foods as well as animal food seems to be indicated by his vitamin requirements. Fruits, leafy vegetables, and unpolished grass seeds are essential to a normal growth of the child today, as well as to the continued healthy existence of the adult. These requirements must have developed through the long-continued use of such foods.

Characters distinguishing man. Another series of internal variations were those which early distinguished the mentality of the human stock from that of the evolving ape. Humanity differs from the rest of the higher mammals in its prolonged childhood, in its higher degree of reason and self-consciousness, in the possession of articulate speech and a religious sense, and in the use of fire and the manufacture of tools.

The increased intelligence of the rudimentary human group necessitated the growth of more and more nerve connections after birth. The human organism thus came to need a longer period of preparation for adult life than did the lower animals. This resulted in the prolongation of childhood (see page 200).

A beginning in reason and self-consciousness may be observed in many of the higher mammals. A considerable amount of reason is exhibited by the dog, cat, horse, elephant, and apes, while the sense of shame in a dog shows that he has a consciousness of self.

After the first incoming of the speech center in the brain, articulate speech must have developed slowly. In "Almost Human" R. M. Yerkes, an American student of the intelligence of primates, remarks that apes fall short of human beings chiefly in their inability to learn to talk. Speech areas are indicated on the skull of the upper Pliocene man, Eoanthropus, and in all later fossil men. The absence of articulate speech in the apes and its presence in Pliocene man suggests its development during the middle or the early Tertiary.

Clive Bell, in his interesting book, "Art," defines the religious sense as "the sense of the reality of the ultimate." Religion, according to Archbishop Trench, expresses the outer form which the inward spirit of devotion assumes. According to these definitions all races of mankind today possess the religious sense; even the most degraded have fetishes. Many fossil races of man had small images, probably to be interpreted as fetishes, while the Neanderthals and Cro-Magnons of the Pleistocene buried their noble dead with more or less religious ceremony.

Fire is known to have been used by man from the early Pleistocene to the present, though it was doubtless used long before that time. Tools manufactured by man are known from the Pliocene to the present.

TOPICAL REVIEW

Arboreal life.
Lemuroid ancestors.
Early anthropoids.
Large anthropoid stock.
Environment for the development of man.
Diet of early man.
Characters distinguishing man.

CHAPTER XVIII

EARLY RECORDS OF MAN

The evidence for the existence of man before written historical records lies mainly along two lines, — skeletal remains and cultural records.

SKELETAL REMAINS OF MAN

Human skeletal remains have thus far been found from the upper Pliocene, throughout the Pleistocene and Holocene, to the present, through a period of possibly two million years.

Pliocene man. Among the most ancient undoubted human remains thus far found is Eoanthropus, the "dawn man." These remains were found at Piltdown, in Sussex, England. They are probably of Pliocene age, since they are associated with typically upper Pliocene elephants and other animals. Parts of two individuals were found two miles apart. Associated with portions of the skeletons were a few bone implements and very primitive flints with trimmed edges. Man of this age is seen to have had a flat vertical forehead like the modern Bushman, a very thick skull, a chimpanzee-like jaw, and a surprising brain capacity for so early a period, — 1070 cubic centimeters, exceeding that of the existing Indian Vedda tribes by 70 cubic centimeters (Fig. 23).

The possible presence of a later Pliocene or early Pleistocene man in eastern Asia was announced in 1926 by Dr. Andersson of the Geological Survey of China. The evidence consists of two teeth of a primitive human type found at Chou Kou Tien, southwest of Peking, and associated with a late Pliocene or early Pleistocene fauna.

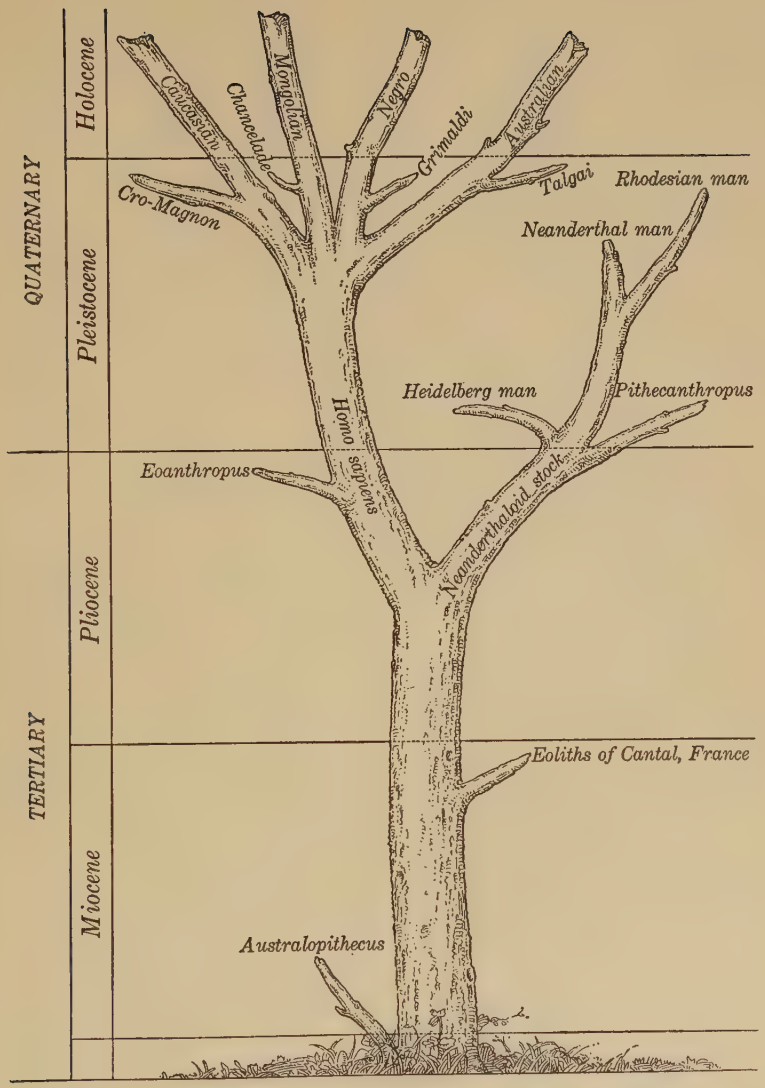


Fig. 23. Evolution of the family of man, the Hominidæ

Pleistocene man. The skeletal remains of man thus far found in the Pleistocene indicate at least five species. Four of these Osborn has grouped together under the Neanderthaloid stock. They appear to be confined to the lower and middle Pleistocene. The fifth species is that of modern man, *Homo sapiens*, which makes its appearance in the upper Pleistocene.

Neanderthaloid stock. One of the earlier offshoots of this stock is the Heidelberg man (*Homo heidelbergensis*), known only by the lower jaw. This was found in 1907 in the lower Pleistocene interglacial deposits of Mauer, near Heidelberg, Germany. It is apparently related in an ancestral way to the later Neanderthal race.

Another very primitive type of early man is *Pithecanthropus erectus*, found at Trinil, central Java, in 1891. The remains, consisting of an imperfect skull, with a brain capacity of 940 cubic centimeters, two molar teeth, and a thigh bone, are probably early Pleistocene in age. These fossils indicate an undoubted man but one having many primitive characteristics. The inside of the cranium shows that the speech center was only about half as extensive as that of modern man.

The low-browed Neanderthal race (*Homo neanderthalensis*) is represented by the remains of some forty individuals from many different parts of Europe and also by numerous implements from Europe, eastern and southwestern Asia, and northern Africa. The first well-preserved skull of ancient man, recognized as such, belonged to this race. This was found at Gibraltar in 1848. The first well-described specimen of the race was found in 1856 in the Neanderthal, in a cavern near Düsseldorf, Germany. Since that time numerous caves, especially in France and Belgium, have yielded skeletal remains. Portions of some ten skeletons, apparently the remains of a cannibal feast, were found in Croatia. More recently two Neanderthaloid skeletons were found in a cave in Crimea, and a rather advanced type of Neanderthaloid

skull near Capernaum in Palestine. The Neanderthaloid stock is characterized by the possession of projecting eyebrow ridges, low, retreating foreheads (with correspondingly low forebrain), massive jaw, and retreating chin (Fig. 24).

Another race of man belonging to the general Neanderthaloid stock, but more primitive or possibly degenerate, is the Rhodesian man (*Homo rhodesiensis*). This very low-browed type is known by portions of the skeletons of two individuals found in the Broken Hill mine in northern Rhodesia.

Fig. 24. Comparison of human skulls

A, a primitive representative of the Neanderthal man; *B*, a modern white man

The skeletons were incased in a metallic cast of zinc silicate formed by the dripping of concentrated waters from the roof of the cave. This cast, which would have shown the shape of the man's body, was unfortunately destroyed by the negro miners; but several bones, including an almost complete skull, were preserved.

Although this African man had a coarse, bestial neanderthaloid skull, he stood erect, not with knees bent, as did *Homo neanderthalensis*. The latter species of man disappeared from Europe abruptly during the upper Pleistocene, but may have continued living in other regions. *Homo rhodesiensis* may represent such a descendant living in Africa, which in the course of subsequent ages attained an upright position. With these skeletons were associated many postglacial animals which

are still living there. They appear to have much in common with the ancient Australian race.[1]

Homo sapiens. The modern species of man is known from the Pleistocene of Europe by three distinct races.

1. *The Grimaldi race.* The earliest representatives of this modern species to find their way into Europe were members of a negroid stock which may have evolved upon the African continent. They are known from two skeletons found in the Grimaldi caves, near Menton, in southeastern France. The lower leg is very long in proportion to the thigh, the forearm is a similarly disproportionate part of the whole arm, and the lower limbs are long in relation to the upper. These characters are true of modern negroes, but in the Grimaldi they are present in an exaggerated degree. The skulls are also typically negroid. According to Boule the Grimaldi have much in common with the present Bushmen of South Africa.[2]

2. *The Cro-Magnon race.* The most advanced race known from the Pleistocene is represented by some twenty individuals and very many culture deposits. They were men of great stature, averaging six feet, and of large brain capacity (about 1550 cubic centimeters). The first remains of this race to be described were found in the cave of Cro-Magnon in a limestone cliff overlooking the valley of the Vézère, near Dordogne, France.

3. *The Chancelade race.* This type of man was of short stature, a little over five feet tall. The name is from Chancelade, near Périgueux, in western France. Several workers, notably Sollas and Boule, suggest that the present-day Eskimos are the direct descendants of this race. Both races are of short stature and are similar in every feature of the skull, including its peculiar keel-like top.

Belonging to *Homo sapiens* and closely related to the ancient Australian race are two skulls from Wadjak in Java and one from near Talgai, Queensland, Australia. Both are probably of Pleistocene age.

[1] M. Boule, Fossil Men. [2] Ibid.

Holocene Man. From the beginning of the Holocene to the present the skeletal remains of man have been found in increasing abundance. The beginning of this modern period saw the invasion of Europe by many peoples with a higher state of culture, the Neolithic.

It seems probable that man's appearance has changed very little from the Neolithic Europeans to the present inhabitants. The teeth of the former were more regularly placed than in modern man, and the incisor teeth at rest met edge to edge. In stature and form of head they differed little. Yet such a specimen as the Tilbury man was found in the Thames valley, in England, beneath thirty-one feet of strata. That is, this modern-appearing Neolithic man lived in this region when the river flowed in a channel more than thirty feet below its present level. When northwestern Europe was at this elevation the North Sea must have been a land area, and consequently England was united to the Continent.

CULTURAL RECORDS OF MAN

One of the most important lines of evidence for the existence of man in ages prior to the present is the record of his handiwork. Since the ability to make implements implies a mental and physical development above that of any other animal form, their presence is taken as evidence of the existence of man. Indication of the use of fire is evidence in the same direction. Cultural records for the earlier ages consist mostly of bone and stone implements, since any clothing or wooden implements would have decayed before now. Gradually, as man evolved, there appear also specimens of etching, sculpture, pottery, painting, bronze and iron implements, foundations of stone buildings, and coins.

Cultural remains, when found, may be dated, at least relatively. This is accomplished for the Pleistocene or earlier periods by primarily paleontologic criteria; that is, the animal and plant remains found associated with the cultural objects

are compared with their already known succession throughout the world. Secondarily, dating is for all periods a question of superposition, of succession in time, especially when the implements etc. of a later culture bear evidence of having been evolved from an underlying earlier culture. The nine successive cities of Hissarlik (Troy) are revealed through a thickness of fifty feet of sediment. At the base are the remains of a late Neolithic settlement, about 3000 B.C. (the first city), and in the upper beds the ninth (Roman) city, about 3500 years later. The sixth city was that of the Trojan War. In the Pleistocene the Mousterian culture is found developing from the Acheulian at various localities in western Europe, while beneath this is found the more primitive Chellean culture. These three cultures occur in unbroken succession in various places, as on the Marne in France.

The various implements indicate much concerning man's state of culture and manner of life, and the remains of plants and animals found with these implements, and the geological character of the deposits associated with them, enable us to understand the climatic conditions to which he was subjected.

The hunter stage. Since humanity has been attained, two advancing stages of culture may be recognized, — the hunter stage and the agricultural stage. These are not mutually exclusive, but represent successive dominant emphases. During the earlier (the hunter) stage, man eats what he finds already developed by nature around him, — the wild fruits, grains, nuts, roots, leaves, and (among animals) eggs, fish, birds, and mammals. These he may modify somewhat by artificial heat, but they are dominantly the product of undirected nature. Man merely hunts for them.

The hunter stage is repeated in the development of the child. He delights in searching over hills and through woods, especially for things to eat. Innate in him is the feeling that to the finder belongs the food. Only slowly through experience and precept does he acquire the concept that what he finds

may belong to someone else. Camp life is dear to his heart. The many tasks incident to establishing camp, the preparation and eating of food in the open, the sitting around a camp fire, especially at night, and talking of things of the wild, are constant sources of pleasure to him. Grown-ups also naturally find such a life very restful, as it brings into action the inherited nerve paths used for ages by their distant forbears.

Since this early hunter stage is a primitive stage in the development of humanity,

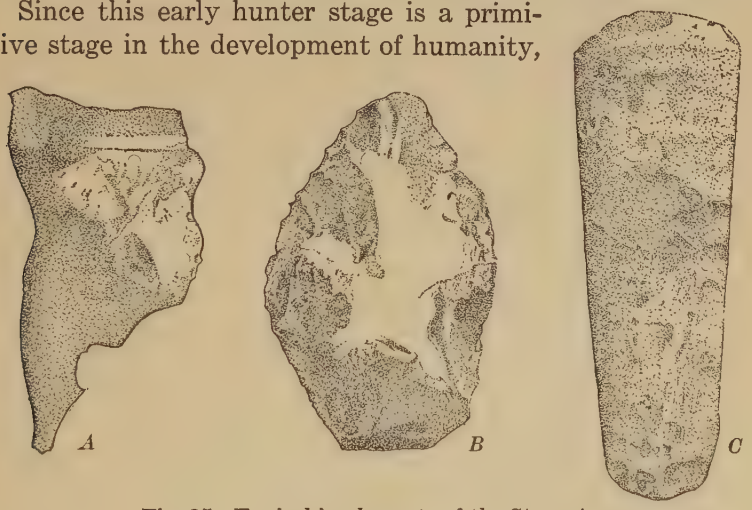


Fig. 25. Typical implements of the Stone Age
A, eolith; *B*, paleolith; *C*, neolith

all the other characteristics of man at this time would naturally be primitive. Hence any of these would show in general the same mental and cultural advance. The degree of development of the stone implements is usually chosen to subdivide this hunter stage into cultural periods because such implements are preserved through the ages, as usually neither decay nor solution by percolating waters can destroy them. The hunter stage may then be subdivided according to the perfection of man's implements into the Eolithic (Dawn of Stone) and the Paleolithic (Old Stone) ages of culture (Fig. 25).

The kind of stone most utilized by man in the various ages of stone culture is flint. It has an almost universal distribution, is very hard, and breaks with a sharp and comparatively straight edge. Obsidian, or natural glass, is also desirable but is very local in its distribution.

Eolithic age. Man in this very early stage must have depended for protection and food primarily upon his speed and agility, and upon the quickness and dexterity of his arm and hand. Doubtless his principal tools, both in food-getting and in protection, were the wooden club and hurled stones. These were no doubt aided by poles for procuring fruit and nuts that were beyond his reach, and by sharp stones or bone for cutting up animals and for scraping skins for clothing or shelter. He still doubtless climbed trees for food and at times for protection.

The child repeats this stage today. His legs increase in length more rapidly than his arms. He delights in climbing trees and in games of running and hurling stones or balls. He feels the need of a stick while on a tramp, and anything that cuts is dear to his heart. Modern educational methods recognize these basic impulses and offer opportunities for the exercising and training of arms and legs as a preparation and later accompaniment for mental work.

Although this stage of culture was probably at first most dominantly one of the use of wood, and later of bone, its only identifiable remains that were capable of preservation for long ages are the stones which man has made use of for scrapers, weapons, etc. Most of these had been shaped entirely by natural forces, but man had modified a few so that they would cut better, and had chipped off inconvenient corners so that they would fit his hand more perfectly. These stones, both those entirely shaped by nature and those slightly modified by man, are known as eoliths, and hence this stage is called the Eolithic stage of stone culture. The Semang of the Malay Peninsula are in this culture stage, since they apparently use only such stones as they chance to find. The

Table XI. Successive Stages of Man and his Cultures

	Climatic Conditions	Man	Cultures		Archeological Divisions		Time Estimate for Europe
							B.C.
Holocene	Completion of oceanic depression to present level (climate as today)		Agricultural stage	Introduction of Roman culture into Gaul Iron in current use in Egypt and Chaldea about 1300 B.C.	Metal Age	Iron	
Holocene	Gradual rise of depressed lands (climate warmer than today)	*Homo sapiens:* Modern races	Agricultural stage	First bronze objects in Egypt and Chaldea about 3500 B.C.	Metal Age	Bronze	1000 2000
Holocene	Ocean waters flooding depressed lands		Agricultural stage	Neolithic culture began in southwest Asia about 18,000 B.C.	Stone Age	Neolithic	7000
Pleistocene	Ice front retreated to southern Sweden about 12,000 B.C.	*Homo sapiens:* Ancient Chancelade race, Cro-Magnon race, Grimaldi race	Hunter stage	Magdalenian, Solutrean, Aurignacian	Stone Age	Paleolithic	12,000
Pleistocene	Würm (Wisconsin) glacial advance (fourth)						
Pleistocene	Third interglacial (brief)						
Pleistocene	Riss (Illinoian) glacial advance (third)	*Homo neanderthalensis*		Mousterian, Acheulian, Chellean			
Pleistocene	Second interglacial (warm faunas)						
Pleistocene	Mindel (Kansan) glacial advance (second)						400,000
Pleistocene	First interglacial (warm faunas)	*Homo heidelbergensis*		Cromerian			
Pleistocene	Günz (Nebraskan) glacial advance (first)						1,000,000
Pliocene	Warm faunas and floras	*Eoanthropus*		Foxhallian		Eolithic	7,000,000
Miocene	Warm faunas and floras						19,000,000

determination of eoliths has led to much controversy, since it is often a debatable question whether a given stone that has been shaped mostly or completely by nature into a tool or weapon has been used by man. If no other evidence, such as fire, bone implements, and skeletal remains, is present, the geological situation must be such that the play of natural forces — currents of water, landslides, etc. — could not have produced them, and that nothing except the agency of man could in the past have carried them into the sediment where they are now found. Stones rightly or wrongly called eoliths have been described from all periods from the Miocene to the present.

Paleolithic age. Gradually to the slight alteration of wood, bones, and stones found ready at hand would succeed the deliberate shaping of such material into tools and weapons after a design existing in the maker's mind. This deliberate working out of a definite plan characterizes the Paleolithic culture age. Such mental concepts and the necessary co-ordination of nerves and muscles to carry them out marks a great advance in humanity. The European remains of this age are of two geological periods.

1. *Pliocene man.* The type of man from southern England known as Eoanthropus belonged to a very early stage of this culture, or possibly to a late stage of the Eolithic. Markings on the inner side of the skull indicate that he had speech areas and a well-convoluted forebrain. He was obviously a reasoning, talking individual. Of his implements (those offspring of his brain and hand which give us some conception of his culture) a few bone and flint forms are known. Those flint tools that are preserved consist of rough spearheads, hide dressers, and hammer stones for use in flint-flaking. The most authoritative student of this culture, J. Reid Moir, states that this type of implement would be the natural result of the earliest efforts of man deliberately to shape flints to his needs.[1]

[1] *Natural History*, Vol. XXIV (1924), pp. 637–654.

If the Foxhall race, known only by flint tools from Ipswich, Suffolk, England, is contemporaneous, the use of fire is indicated in the crackling exhibited by some of the flint implements.

2. *Pleistocene man.* The numerous remains of man from the Pleistocene period may be classified roughly into two great groups: the neanderthaloid, dominant during most of this period, and the earliest known representatives of modern man, *Homo sapiens,* who attained prominence during its closing millennia.

a. Neanderthaloid races. Europe, Asia, and Africa were dominated during the early and middle Pleistocene by a variety of races possessing certain structural characteristics in common. They all had thick, heavy bones with large joints. The head was characterized by strong, projecting eyebrow ridges, a very low, retreating forehead, and massive jaws with a retreating chin. Quarry sites for flints, camping grounds, implements, and skeletal remains of these races are found in localities ranging from Spain to China, and from Great Britain to central Africa. (The cultural stages of the Neanderthal races are considered in the Appendix under "Succession of Pleistocene Cultures.")

These races appeared in Europe at the beginning of the Pleistocene and continued until the fourth (last) glacial advance, a period extending over nine hundred thousand years according to the radioactivity time scale. During this enormously long time the bones became less massive and the brain increased in capacity. Accompanying this increase in intellectual equipment is an increase in number, variety, and perfection of the manufactured implements of the chase, war, and industry.

b. Homo sapiens. During the upper Pleistocene there appeared in Europe three different types of man so modern in appearance that they undoubtedly belonged to the same species (*Homo sapiens*) as man of today. Individuals of these types in the Paleolithic stage of culture in the remote Pleistocene time display the modern characteristics of high forehead,

great cranial capacity, reduced eyebrow ridges, and projecting chin. Specimens of the various types of this advanced species have been found mainly in or before caves, in position of ceremonial burial, usually with implements and food by their side. Among these groups are the Grimaldi, a negroid race; the Cro-Magnon, corresponding somewhat (according to Boule in "Fossil Men") to the white race; and the Chancelade, a type nearest to the present yellow race.

Not only do these Paleolithic races of *Homo sapiens* differ radically from the Neanderthaloid races in physical appearance, but their culture is likewise of a higher type. (See Appendix, "Succession of Pleistocene Cultures.") In addition to very many different kinds of flint and bone implements for hunting, fishing, war, and domestic uses, such as the harpoon, spatula, shuttle, pin, needle, and blades, there appear the drill, chisel, and polisher for use in sculpture and engraving, and wands for ceremonial affairs. The people of the Cro-Magnon race were especially expert sculptors, engravers, and painters.

Such a radical change in physical appearance and in culture, from the men of the latest Neanderthal (Mousterian) epoch to those of the earliest epoch (Aurignacian) of *Homo sapiens*, in the immediately following epoch in Europe, implies an enormously long period of time during which the people of this later race had elsewhere developed. The greatly increased size of their brains, their powers of observation, reasoning, and design, their ability in tool-making, and their capacity for social, political, and moral organization — in general, their much greater creative faculty — must have required hundreds of thousands of years to evolve.

In certain environments a nomadic, pastoral stage doubtless intervened between the hunter and agricultural stages. This would be especially true in regions of limited tree growth and slight rainfall.

The agricultural stage. As far as Europe is concerned (and the very early history of man in Europe is better known than

that of any other continent) humanity remained in the hunter stage until the opening of the modern period, the Holocene. At this time there occurred an invasion of various peoples with a higher stage of culture, the Neolithic. Many of these, while depending somewhat upon the product of the chase, depended still more upon the tilling of the soil for the raising of wheat, barley, millet, etc. So high a degree of agriculture as was exhibited by these people must somewhere have passed through long antecedent development. In some other regions of the earth humanity must have reached the agricultural stage during the Pleistocene and possibly in the Paleolithic age of culture. This probably took place in some semiarid region of the earth where forests and consequently game were scarce, and where an annual overflow of rivers supplied natural irrigation.

Since the tilling of the soil increases the amount of food, agricultural peoples are always more numerous than hunters. It has been estimated that about a thousand tillers of the soil can subsist on the same amount of land as can one hunter. Hence, when agriculturists enter a region, the hunter stage must disappear.

All these early agriculturists belonged to the large-brained modern species, *Homo sapiens*. Human history, from this period down to historic times, has been divided into the Neolithic, Bronze, and Iron ages on the basis of the chief material used for tools and weapons.

Neolithic age. Gradually, as the climate of the lands of the temperate zones became warmer, the distribution of forests and of plants and animals took on its modern aspect. This time is taken as the beginning of the modern period of earth history, the Holocene. It witnessed the invasion of Europe, apparently from the East, of men with a higher type of culture. The invaders still used stone for making their most efficient implements, but since many of these were smoothed and polished as a final stage in shaping, they were more effective than the merely chipped implements of the

Paleolithic peoples (Fig. 25). The higher art of polishing stone implements marks the people of the Neolithic Age (or New Stone Age).

The Neolithic people brought with them a knowledge of agriculture and of the domestication of animals, and consequently initiated tremendous economic changes throughout Europe.

The development of agriculture, especially the cultivation of the cereals, would lead to the development of permanent camps and a gradual abandonment of a nomadic life. There were many villages of half-underground huts, — a type of habitation that spread all over Europe and persisted for centuries. Other villages were erected on piles in lakes. Such are known throughout Europe from East Prussia to Scotland, and south to the Mediterranean, and have been especially studied in Switzerland and Austria. Lake dwellings continued to increase in abundance into the Iron Age. They were made of interlaced twigs covered with clay and thatched with straw, raised upon high piles driven into the edges of lakes. They were gathered into villages, often extending several hundred yards along the shore, with which each village was connected by a gangway. Dugout canoes were in common use. Many lakes are entirely surrounded by the remains of such villages. Each dwelling apparently had its own hearthstone and stones for grinding meal. The charred remains of food, clothing, etc., buried in mud at the base of the piles, give evidence of the frequent destruction of buildings by fire. This charring has been the means of preserving much material which would otherwise have been destroyed, such as portions of garments of skin and of woven flax, fruits, grains, and bread.

Some communities, apparently less advanced, lived largely upon mollusks and fish. They usually established their villages at the head of a bay by the side of a fresh-water stream, so that food, water, and wood were accessible. The waste was allowed to accumulate around their huts in heaps

that are now known to us as shell-mounds, or as kitchen middens (see Appendix, "Kitchen Middens"). These have been especially well studied in Denmark.

Among the refuse of these various villages, especially from that accumulating beneath the lake dwellings, have been found numerous weapons of war and of the chase, implements for tilling the soil and harvesting, bones of the animals eaten, and grain, fruits, and nuts. Among the more important weapons were the bow and arrow and the polished stone ax. The knowledge of agriculture was naturally rudimentary compared with that of today. A variety of plants, however, such as wheat, barley, and millet, were cultivated, and from them was made a rough kind of bread. These grains are not native to Europe, and must accordingly have been introduced into Europe by these early farmers. Clothing was made of skins and of the flax that was cultivated. These people made use of such native plants as the apple, pear, strawberry, blackberry, raspberry, hazelnut, English walnut, and beechnut. The English walnut (*Juglans regia*) is now restricted, as a native, to Greece and eastward into the Himalayas, but in earlier times it must have flourished around the Swiss lake dwellings. The apple was used in its wild state throughout Roman times and down to within the last few human generations. Modern man gets rid of the woody tissue and increases the pulp and size of the fruit. The wild apple is small, with a diameter of from 1.5 to 3 centimeters. The wild pear was similarly made up of much woody tissue. Pottery was used for cooking. The bones of mammals found among the remains of Neolithic hearth fires are not split for getting at the marrow, as were the bones found in upper Paleolithic deposits.

The newcomers brought with them from the East the shorthorn and longhorn cattle, pigs, and probably also the ox, sheep, and goat. After entering Europe they captured and domesticated the European forest horse and a plateau type of pony, and the Celtic shorthorn cattle. That they

also domesticated the dog is shown by their drawings. These domestic animals, however, continue rare until the incoming of the higher Bronze Age civilization.

The methods adopted by Neolithic man for extracting flint for their implements are illustrated in several ancient flint mines in England and Belgium. The early miners excavated shafts in the chalk rock to depths of from ten to forty feet, and from the bottom of the shafts tunneled galleries along the seams of the flint. The implements used in this work were picks of red-deer antlers and rude flint tools. Some of the galleries are nearly thirty feet long, and probably were artificially lighted. Perhaps cups cut out of chalk, such as have been found in some of the mines, served as these primitive lamps. It was during this age that many of the surviving megalithic monuments were built.

While the invasion of the Neolithic men produced vast changes among the peoples already in Europe, the effect of changing climate upon the animal life and thus upon man may likewise be observed. In certain caves of western Europe the remains of the Paleolithic and Neolithic periods are separated by layers of stalagmite which must have taken an immense period of time to form. Certain other settlements show by their cultural remains uninterrupted habitation from Paleolithic into Neolithic times. It thus appears that while some of the old settlements of Paleolithic time were abandoned and whole communities followed the retreating reindeer northward, a part of the ancient population still lived in western Europe, finally amalgamating with the newcomers who in a constant stream of immigration brought a new culture from the East. In the same way future paleontologists will be able, from a study of the intermingling of two cultures in America, to speak of the new culture from the East.

Metal Age. The duration of the Stone Age is measured in terms of geologic time. It persisted millions of years (see Table XI). With a knowledge of the working of metals, however, and with their increasing use, human culture evolved

more rapidly. The incoming of metallurgy is comparable in importance to the previous advance gained by the use of fire.

The Metal Age may be divided into the Bronze, Iron, and Historical periods. The first two derive their name from the metal in dominant use; the last, while really a prolongation of the Iron period, is distinguished by the preservation of knowledge by means of writing.

There is naturally no sharp line of demarcation between the Stone Age and the Metal Age, or between the Bronze, Iron, and Historical divisions of the latter. Stone implements continued to be used long after the introduction of bronze. The Bronze and Iron periods overlap in the same way. This mixture of different types of implements is due to various causes. The new material is rare at first; also, the older still serves better for many purposes, as we in the Historical period today use grindstones and whetstones. Moreover, there is a natural disinclination to depart from old usages, and, in addition, motives of religion give to methods and appliances of ancient days a sanctity which keeps them in use long after they have been discarded for ordinary purposes. Thus the Egyptians continued to use stone knives for embalming the dead, centuries after metals had come into common use.

As the incoming of successively higher plants and animals does not usually result in the destruction of the older and lower ones, so varied stages of culture may exist in different parts of the earth at the same time. In each case the less advanced occupy areas not desired by the higher. As late as A.D. 1500 probably more than one half of the lands of the earth were inhabited by people in the Stone Age of culture, mostly Neolithic, while much of the remainder was in the Bronze period or the early Iron period. Such overlapping renders the matter of chronology difficult. The Neolithic seems to have been everywhere of long duration. Its beginnings in Egypt may date back twenty thousand years, while in Europe it is generally considered to cover the period from 6000 or 7000 B.C. to 2500 B.C.

1. *Bronze period.* It is probable that copper was the first metal of which implements were made. This material is used in many of the most primitive forms, is widely distributed, and is easily worked. There is, however, no evidence for a universal copper stage of culture. Knowledge of the superior qualities of the alloy of copper and tin, producing bronze, seems in most cases to have followed directly upon the use of stone.

Where the use of bronze originated is not known. It may possibly have arisen independently in many areas. A bronze rod found at Medum in Egypt dates from 3700 B.C. In Mesopotamia there was found a bronze statuette of 2500 B.C. Wherever bronze came into use its superiority over stone and copper caused its widespread adoption throughout the ancient world. Its use in Great Britain and Scandinavia seems to have begun not earlier than 1800 B.C., — much later than in the Mediterranean lands. Although gold was known in various parts of the world in the Neolithic age, gold ornaments in abundance, including bracelets, collars, and clasps, make their appearance first in the Bronze period.

In England, Stonehenge and the abundant burial places known as round barrows appear to have been built during this period.

2. *Iron period.* This period is marked by a general adoption of iron for domestic, agricultural, and military tools and weapons. In Europe it began about 1000 B.C. in classical lands, and about 500 B.C. north of the Alps. Lake dwellings, though present in the Neolithic and Bronze times, were most abundant in the early years of the Iron period. At times they were erected on piles, and at times on floating islands built of logs. Of the latter type were the Irish and Scottish crannogs, whose use continued through the Middle Ages, one being taken by assault in the reign of Queen Elizabeth.

3. *Historical period.* The Historical period may be considered to date from the time when man developed the means of preserving his knowledge and handing it on to succeeding

generations through the agency of characters written upon any material. The use of iron and other metals continued and enlarged, but the new possibilities that lay in the written record introduced a definitely new age of culture. In northwestern Europe it began with Julius Cæsar, a short time before the beginning of the Christian Era. In the regions about the Mediterranean it began much earlier. This is especially true of Egypt and Mesopotamia. In the latter region there is a cuneiform inscription from the first dynasty of Babylon, 5000 B.C.

Apparently the Western Hemisphere has had no influence upon the evolution of man other than upon the Indian races found here when the whites appeared.

HAS MAN ADVANCED?

Biology shows man to be a certain kind of animal,—the human animal. He has very much in common with the wolf, bird, and fish, but none of the animals can be defined by the characters common to all. It is the special characteristics that make the species. Man's inheritance of the backbone of the fish does not limit his characteristics to that class. He inherits attributes from numerous animal ancestors; but if he allowed any of these to dominate his life, he would dehumanize himself. The attributes which make him the modern *Homo sapiens* dominate the other characteristics. The attributes of his particular species include reason, foresight, inventive talent, and sentiments so characteristic of the human species as to be called humane sentiments.

The most easily recognized evidence of advance in man from the Tertiary to the later Pleistocene is the increase in cranial capacity, that is, in his intellectuality. This is conspicuous. From the upper Pleistocene to the present the change in physical form is comparatively slight, the principal evidences of evolution lying in the changes that he has wrought in his cultural evolution. There is much discussion of the

reality of progress; this is largely a question of how progress is defined. That there has been marked progress in adaptation of the environment to his needs there can be no doubt. The discoveries that he has made, his increasing knowledge of natural forces and their control, and the machines that he has invented have reduced the labor of supplying primitive bodily necessities and have supplied comfort and leisure to an ever-increasing proportion of mankind. This has been well expressed by J. McKeen Cattell as follows:

> Science has made it possible for each to work at routine tasks half as long as formerly and at the same time to consume twice as much wealth as formerly. Fourteen hours of labor, shared by women and children, once provided hovels, lice and black bread for most people, luxury for a few. Seven hours of labor will now supply comfortable homes, warm clothes and healthful food for all.[1]

Thus, as we study man's progress through the early and later hunter stages and the early agricultural stages of the Neolithic peoples, then successively through the historical nations (Sumerian, Babylonian, Egyptian, Grecian, Roman), and then from medieval civilization to modern scientific civilization, we attain to a rational faith in man's capacity for infinite progress.

Freedom not only of the body but of the mind is increasingly recognized as due to all classes of peoples to the degree that modern conditions of coöperation permit. Freed from a large part of his material cares, through control of his environment, in an atmosphere of increasing freedom supplied by his heritage of social evolution, man of the future has limitless possibilities of evolution along those lines which are open only to his species. Man's hunger for growth and conquest cannot be sated with dominion over the physical environment. Who can foresee into what realms of mental and spiritual achievement he may advance?

[1] *Science*, January 1 and 8, 1926.

TOPICAL REVIEW

Skeletal remains of man:
- Pliocene man;
- Pleistocene man;
  - Neanderthaloid stock;
  - *Homo sapiens;*
- Holocene man.

Cultural records of man:
- The hunter stage;
  - Eolithic age;
  - Paleolithic age;
    - Pliocene man;
    - Pleistocene man;
      - Neanderthaloid races;
      - *Homo sapiens.*
- The agricultural stage;
  - Neolithic age;
  - Metal age;
    - Bronze period;
    - Iron period;
    - Historical period.

Has man advanced?

CHAPTER XIX

EFFECT OF ENVIRONMENT UPON MAN

EFFECT OF CONTRASTS UPON ENERGY

Since our bodies, like those of all mammals, have evolved a high, stable temperature, any attempt to lower it is followed by a vigorous response of the body to raise it, for instability of body temperature would mean death. The principal effect of the cold sponge bath is its stimulation of all the bodily organs. After it man is wide-awake mentally as well as physically. He has received energy from the contrast between the warm body and the cold water.

The effect of seasons. In the temperate zone man finds that it is easier to work in the cooler months of fall and spring, because of the stimulation brought about by the contrast between the warmth of the body and the cold air.

This effect of the seasons may be observed when output of work is measured. Huntington, in "Civilization and Climate," has summarized observations on many factory operatives. Those especially studied were of mixed European descent, all engaged in piecework, manufacturing such small hand-work articles as screws. They included five hundred persons in three different cities of Connecticut, and several thousand persons in Pittsburgh, Pennsylvania. All the factories showed a low minimum output in winter (late January and early February), a rise to a spring maximum in May and June, a gradual rise to a higher maximum in October and November, and a rapid descent to the winter minimum. There was at times a slight secondary minimum in July and August. The work of these operatives is paralleled by the statistics of workers from the other New England states and from New

York to Georgia; also by examples from Europe and Japan. Maximum efficiency was neither during the extreme cold of winter nor the extreme heat of summer, but during the more moderate spring and fall months, and especially on the colder fall days when the body was stimulated by the change from the hot days of summer. In Florida, tabulation of the work of cigar operatives shows that the period of maximum efficiency is usually winter, — the time of greatest temperature contrasts.

These conclusions would lead us to expect that, other factors being equal, the most efficient peoples are within the

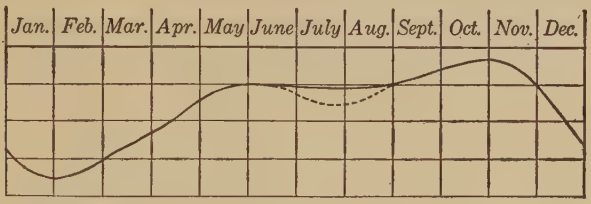


Fig. 26. Effect of seasons upon capacity for physical work

temperate zone; for the energy available for work, that is, above what is needed for the maintenance of the body, decreases both poleward and equatorward from the temperate zone. In frigid climates too much energy is needed for maintaining the body temperature at 98.6° F.; in the humid tropical climates it is the cooling mechanism of the body that is overtaxed.

It is still a question whether tropical regions with sufficiently high altitudes to have a temperate climate furnish enough contrasts, as well as enough oxygen, to give a high level of energy. The ancient Inca civilization suggests the affirmative.

The effect of frequent changes in weather. In addition to the alternation from day to night and the changes brought about by the progression of the seasons there are changes in weather which produce contrasts in humidity as well as in temperature. When the temperature and humidity remain

the same for many days in succession, with little change during the night, the amount of work that man can easily do is relatively small. Monotony of environment tends toward stability. It is fortunate at such times that there are internal sources of energy, some of which, like hunger, are constant stimuli. When the temperature and humidity rise or fall the amount of work done increases. This being true, it follows that certain regions develop a higher average level of energy than do others. Eastern Europe (Russia and the neighboring countries) has very low humidity, with long, monotonously cold winters and long, monotonous summers. Central and northwestern Europe has a comparatively high humidity, with variable winters and summers. In this region, as well as in the eastern portion of North America, Japan, southeastern Australia, and New Zealand, the variability of winter and summer is due to frequent climatic changes caused by cyclonic storms. These are almost the only parts of the globe where such storms prevail in great numbers. Cyclonic storms are great whirls of air, usually several hundred miles in diameter. In them the air at the surface of the earth moves spirally inward to a center of low pressure, while the whole area moves eastward and poleward. Since they are accompanied by shifting winds, considerable areas of cloud, and small areas of rain or snow, they are also accompanied by rapid changes in temperature and humidity. Such harsh contrasts set the blood coursing more rapidly and increase bodily energy.

In some regions, as western temperate North America, somewhat similar contrasts arise from the heating of the land by the sun during the day and its cooling by winds from the ocean at night.

Summary. As the human machine needs food at frequent intervals to remain at a high level of health, so it needs frequent changes of temperature, considerably below the body temperature and accompanied by a not too low humidity, to remain at a high level of energy, physical and mental. The

effect of a single climatic change is short-lived, as is the effect of a single meal. Comparatively low temperatures are needed to keep the blood moving and the system in tone. The contrast between the low temperature of the air and the high temperature of the body is like the difference of level of two water bodies in causing the production of energy. According to Huntington, man works best physically when the temperature is about 50° F. at night and 70° F. during the day; mentally, when it is about 32° F. and 50° F., with humidity about 75 per cent.

The most important climatic factors in the production of these changes are the mean temperature month by month (the seasons), the amount of temperature change from day to day (the weather), the change from day to night, and the relative humidity. Apparently the regions most fully exhibiting these factors are within those portions of the temperate zones where the humidity is not too low. In these the progression of the seasons gives stimulating temperatures during a part of the year (in the median portion this is spring and fall). They are the areas where frequent cyclonic storms make all seasons, even the otherwise monotonous ones, stimulating, or where the daily range of temperature produces the necessary contrasts.

The ancient civilizations of Egypt, Babylonia, Chaldea, Greece, and Rome all lay north of the tropic of Cancer, within the temperate zone. They flourished at a time after the retreat of the last glacial period when apparently the cyclonic storm belt lay south of where it is today; for it was in these regions a time of greatly increased rainfall, as is shown by the numerous dried-up lakes.

The racial characteristics determined by heredity, and the social environment, including education, the degree of culture of the community, etc., determine the direction in which a nation's energies shall be expended; the climate is apparently the factor that determines how great and persistent these energies shall be.

Though man, the highest product of evolution on earth, has many internal stimuli to exertion, such as anger and joy, hate and love, and the desire of creation in art, science, etc., he is still subject in a remarkable degree to such external influences as food and climate.

Since man partially makes his own climate in his house, he can produce here, if he will, the optimum contrasts of temperature and humidity. When the outside air, with a temperature of 30° F. and a humidity of 70 per cent, is heated in the house to 70°, the humidity is reduced to 12 per cent and the air becomes as dry as the driest desert. Such a condition causes a rapid evaporation from the skin, and the mucous membrane of the nose and throat becomes parched and thus less able to resist the entrance of cold-producing germs.

EFFECT OF ENVIRONMENT UPON FORM

Changes in immigrants to the United States and their children. The descendants of the majority of immigrants to the United States from Europe show a change in height of body and form of head. This was first definitely proved by Dr. Franz Boas in 1908, when, under the direction of the United States Immigration Commission, he took measurements of some thirty thousand immigrants and children of immigrants in New York. His object was to see whether, after living for a time in the United States, any physical differences occurred (1) in adult immigrants in this country, (2) in their children born abroad, and (3) in their children born in this country. Measurements of children began at five years of age.

The work showed (1) that there was no change in the form of immigrants coming to this country after they were fully grown; (2) that children born abroad, coming to this country as children, change little, but in the same direction as those born here; (3) that children born in this country show a distinct difference from those born abroad, — a difference

proportionate to the length of time the mother has resided here. The difference is more marked in children born after the mother has lived here ten years than in those born after five years of residence. The distinction between foreign born and American born is sharp and much greater than between children born earlier and later in this country.

The principal groups studied were (1) the Scotch; (2) East European Hebrews, from Poland and the neighboring regions of Russia, Germany, Austria, Rumania, etc.; (3) the Bohemian group (Bohemians, Slovaks, Hungarians, and Poles), from the same general region as (2); and (4) Sicilians and south Italians (that is, south of Rome). The character of the changes is shown in Table XII.

TABLE XII. CHANGE IN CHILDREN OF FOREIGN PARENTAGE BORN IN THE UNITED STATES

STOCK	STATURE	FORM OF HEAD
1. Scotch	No change	No change
2. East European Hebrews . .	Taller	Longer and narrower
3. Bohemian group	Taller	Shorter and narrower
4. Sicilians and south Italians .	Shorter	Shorter and wider

The change is probably due partly to a greater variety of food and to better living and working conditions, with climate an accessory cause if not the dominant one. The southern Italians come from a region with long, monotonous, dry summers; the Hebrew and Bohemian groups, from a region with long, monotonous, cold winters; and all go to New York, with its cold, variable winters and warm, variable summers. The contrast from the monotonous to the variable climate would stimulate the body. This urge could produce no physical change in the adult but could be impressed upon the rapidly changing tissue of the very young child (see page 129). Why one group should tend to become shorter and others taller is as yet unknown. The Scotch remain un-

changed for a generation, probably because in their case there is so slight a change in climate.

Changes in the third and later generations of immigrants to the United States. The work of Dr. Ales Hrdlicka apparently indicates that by the time of the third or fourth generation in this country a decided change occurs even in the Scotch. Dr. Boas was concerned with changes in the first generation only. But in "Old Americans," which was published in 1925, Dr. Hrdlicka has carried this study to the third and later generations. Under old Americans he includes those whose parents and all four grandparents were born in this country. These, of course, are at present in a decided minority among the population as a whole. During the investigation, which extended from 1910 to 1924, he took very detailed physical measurements of one thousand old Americans, besides making observations on many more. This work agrees with that of Dr. Boas in showing that the white population of this country has been undergoing a gradual physical change.

The third and later generations born in this country and free from admixture with later immigrant blood show common characteristics, or with only slight differences, for various parts of the United States. In this American type the average height of the men is 5 feet 8.6 inches and that of the women 5 feet 3.7 inches; this exceeds the stature of all the groups of the white race in Europe from which they were derived. There is a slight tendency to spareness. The average size of the head is larger than the average of recent immigrants, with a relatively narrow face and a forehead of medium height and breadth. The eye slits are horizontal as in other whites, the cheek bones below the medium in prominence, and the nose rather long and of moderate breadth. The mouth is of moderate width, the lips of medium thickness, and the ear about the average for the white, that is, intermediate between the small ear of the negro and the large ear of the yellow-brown race. In color of skin they are intermediate between blond and brunet. The hair, similarly intermediate,

is medium brown, straight or nearly so, and of medium thickness. The eyes are light with traces of brown coloring. The hands and feet are rather narrow.

In the development of the American type the influence of the environment is seen. The dominant causes of the greater stature and larger head are probably better food and living conditions, plenty of interesting exercise and study, the freedom of children from long hours of work, and progress in the control of various infantile diseases that retard growth. The climatic factor is seen dominant in the change in pigmentation. The first census (1790) showed that 90 per cent of the American population were of British blood, the remainder German, Dutch, Irish, and French, — a typically blond aggregation. Yet the descendants of these, uninfluenced by other types of immigrants, are not blond. Only one third have light-colored eyes, and only one in about fifteen was found to have truly fair hair. The main function of pigmentation is to protect the skin and eyes against those rays of the sun which would be harmful to the organism. When man moved into chill and damp northwestern Europe, he needed less pigment, and blondness resulted. In America the more open sky is apparently working toward a type intermediate between blond and brunet.

The American type at present approaches nearest to that of Great Britain, but is quite distinct. This will probably vary somewhat in the future, for heredity as well as environment is active. Within the past seventy-five years immigrants have been most numerous from southern and eastern Europe. The result of the amalgamation of this element with the older stock will naturally cause some change, the strength of which will depend upon the strength of the climatic factor. Dr. Hrdlicka, however, believes that this new type will not be far from the American type of the present.

An increase in stature is also indicated by a comparison of college students of the same age for the last fifty years. An average increase of about two inches in this time is shown

by both men's and women's colleges. A comparison of growth curves shows that this difference in height continues from infancy to adulthood.

TOPICAL REVIEW

Effect of contrasts upon energy:
- The effect of seasons;
- The effect of frequent changes in weather;
- Summary.

Effect of environment upon form:
- Changes in immigrants to the United States and their children;
- Changes in the third and later generations of immigrants to the United States.

CHAPTER XX

FOUR INSTINCTIVE IMPULSES

INSTINCT AND INSTINCTIVE IMPULSES

Instinct has been defined as an innate specific tendency of the mind or body common to all members of any one species. Webster's Dictionary describes instinct as an unreasoning prompting to any action, bodily or mental; especially, any inherited tendency, characteristic of a group of related animals, to perform a specific action in a specific way when the appropriate situation occurs. When, for example, the incentive to reproduction comes to birds, each species makes use of its own peculiar building material and has its own type of architecture and its own distinctive building site. Both barn swallows and eaves swallows make their nests of mud, the former constructing within a building, the latter beneath projecting eaves or cliffs. The robin makes use of such a substantial support as the crotch of a tree for its nest of mud and dried grasses. The pendent nests of the orchard orioles and the Baltimore orioles are easily distinguished from each other by their constant shapes. Similar unvarying reaction to this nest-making instinct is seen in such lowly vertebrates as the fishes and reptiles.

The group of four instinctive impulses hereafter considered does not come within the definition of an instinct, for the reaction to a situation is not alike in all particulars for the various individuals exhibiting them. There is, however, a common tendency for all to act in a similar manner under a similar impetus. Such tendency, not due to reason, is called an instinctive impulse. The impulses of self-preservation, of reproduction, of care of offspring or of other members of a herd are instinctive.

THE TWO PRIMARY IMPULSES

The two primary impulses are certain instinctive reactions which are essential to the continuation of any life upon earth. These are the impulses of self-preservation and reproduction. Organisms that do not act so as to protect themselves and that do not take food will die and hence leave no offspring, while those that do take food and protect themselves and yet fail to reproduce will similarly bring their line to a close. Hence it is that these two impulses are so strong in every plant and animal; they have been impressed upon the body cells of an incalculably long line of descendants through the survival of only those parents successfully exhibiting them.

Illustrations of the action of these impulses in the mammals, birds, reptiles, amphibians, fishes, insects, crustaceans, snails, clams, and corals are well known to all. These are just as true of the microscopic one-celled animals. Amœba will retreat from the touch of a rod but will chase a Euglena cyst, thus showing fear and hunger. The roots of a land plant living in a swampy region remain close to the surface, since they can live only where the soil is well aërated; it would mean death in this situation to extend the roots farther downward.

THE PARENTAL IMPULSE

In all the lower invertebrate phyla the animals lead solitary existences throughout life, while the majority of the higher invertebrates and lower vertebrates are solitary except during the very brief mating season. The parental impulse is a great advance upon this solitary condition, for it means a shorter or longer association of the young with one or both parents, and all that this association implies in the development of both parents and offspring.

Today the lowest vertebrates exhibiting the parental impulse in the care of young are representatives of the highest subclass of fishes, the teleosts. Of these the mudfish, stickle-

back, and sunfish are but three of many examples. In the common stickleback of North American streams the male makes a nest of weeds held together by a glutinous secretion of the kidneys. In this nest one or more females lay their eggs, and the male then actively protects from predacious fish both the eggs and the later-developed young. In the fresh-water mudfish, or bowfin (*Amia calva*), of eastern North America both male and female aid in clearing away weeds and forming a shallow depression in the pool. The eggs and young are then guarded by the male alone.

When the parental impulse, expressed in the care given to eggs or young, occurs in the fish, it is only in the male. In these fish fertilization takes place after the laying of the eggs. It is thus natural that the male, the last to have anything to do with the undeveloped young, should be the one in whom there should gradually arise a care of them. Hence, also, it is to be expected that among the reptiles, birds, and mammals, in which fertilization takes place within the body of the female, it should be the mother in which the parental impulse should be expressed more forcibly. She is the last to have anything to do with the eggs or young. Thus, in the very few reptiles that evince any parental impulse it is the female that shows it. The mother crocodile, laying her eggs about two feet deep in sand, lies upon the mound each night, guarding them until noises come from them, when she removes the sand, and each of the young then breaks through its shell. The mother alligator, after covering the eggs with a mass of dead leaves and twigs, digs a hole in the river bank a foot or two from the eggs, and from this point keeps off all marauders until the eggs hatch out. So too with polygamous or polyandrous birds and mammals, it is the female that cares for the young. This is seen in hens among birds, and in the house cat among mammals. To the generalizations just stated there are a few exceptions, such as the rhea and emu among birds, in which it is the male that cares for the young. In the highest groups of birds and mammals both parents care for the offspring.

Length of infancy. Infancy in its broader significance is the time between birth and adulthood. Its length depends chiefly upon three factors: the size to be attained by the adult; the presence or absence, immediately after birth, of the necessity of running; and, most important of all, the intelligence of the adult. The huge elephant requires about twenty-five years to mature, and the whale probably needs as long a time, while the rabbit matures (that is, may begin breeding) in three months.

Among such nomads as oxen and horses it is essential to the well-being of the herd that the newly born young be able to run with their elders almost at once. This ability follows upon the advanced stage of development in which they are born as compared with the helpless state of some other animals whose young are protected. Among the mice, for example, the young are hidden and are born blind, hairless, and helpless.

W. P. Pycraft, in "The Infancy of Animals," thus sums up the third factor, intelligence. "The higher we get in the scale of creatures, the longer the period of infancy and the more the care displayed by the parents for their young." John Fiske, in his "Meaning of Infancy," discusses the necessity for this. For every action of life (digestion, running, etc.) nerve connections must be made between certain nerve centers. When the acts of life are few, as in the simpler animals, all necessary nerve connections form during the egg or fetal period. Hence at birth the young animal is prepared for its life work and can learn very little from others. Consequently, since even this little cannot be passed on through imitation of parent by offspring, one generation is much like another, and of a general low order of intelligence. When, however, an animal has evolved to a point where his experience has become so varied that he must do many things, there is not sufficient prenatal time to make all necessary nerve connections. It thus follows that only the absolutely necessary organs, such as those of respiration and digestion, are made ready before birth, the remaining nerve connections being formed after

birth, during infancy, — the time when the young cannot take care of themselves. It thus follows that infancy is a time of great educability. These later nerve connections are made under the influence of external environment, of which the most important factors are parents and other members of the herd, and, in the higher races of mankind, such social institutions as the school.

In brief, a point is reached in the evolution of intelligence beyond which a part of each individual's growth, with its necessary nerve connections, must be made after birth. Hence growing intelligence makes necessary a longer and longer infancy.

THE HERD IMPULSE

As there occurred during the very early periods of earth history a union of cells that resulted in their greater good, so, with a similar result, there took place during the early Cenozoic a union of many-celled animals. The former resulted in the familiar many-celled plants and animals; the latter, in the herd, or pack. The former represents a physical union, the latter a mental one. Both resulted from the operation of the law, the larger the organism, within the limits set by its heredity and environment, the greater its chance of survival.

The union of individual animals to form a larger group resulted in more gain to the individual than loss. Its freedom suffered in the curtailment of separate action. It must also eat its food in close competition with the other members of the herd. The gain, however, has been most important. Each individual has much greater protection, for here as elsewhere "in union there is strength." Each has a larger and more regular food supply. The strong herbivore herd can eat almost where and when it will. The carnivore pack can capture larger and fleeter animals. The young, moreover, are better protected and thus stand a greater chance of survival to adulthood. This close and constant association of many

individuals would necessarily lead to increase in intelligence and in adaptability, and to the development of many instinctive reactions, known collectively as the herd impulse.

Instinctive impulses to which gregariousness gives rise. Because of the necessity for unity of action among the various members of a herd they develop certain instinctive impulses. (1) They are sensitive to the call of the herd. The sheep not responding will be eaten; the wolf will be starved. (2) They are subject to passions of the pack. Doing things together gives an increase of strength. This is seen in the resistant force of the males guarding the herd from the carnivore pack, and in the rush of the hunting wolf pack. (3) They are susceptible to leadership. In order that a herd may act as a unit and thus show its maximum strength there must be a single leader; otherwise in times needing quick action the herd would be divided and hence lost. (4) They develop recognition marks. These are primarily odors, so that members may be recognized even in the dark; otherwise enemies might enter into the midst of the herd with disastrous results. (5) The herd is the individual's normal environment from birth to death. Hence the animal is happiest when in it. (6) Too great originality in conduct is suppressed, for any marked departure in conduct from the normal tends to expose the individual or the entire herd to danger. The lower the intelligence the greater is this danger. Thus, in the bee originality of conduct is very slight; in the elephant, very great.

The results of these impulses are (7) fixed mental reactions to all happenings and (8) the feeling of duty and of guilt. It is the duty of each member to warn the herd of approaching danger. Hence the stamp of the sheep's foot and the low growl of the dog. Failure to perform his duty would naturally lead to a feeling of guilt. The development of this feeling is well seen in the difference between the dog, a descendant of herd animals (the wolf and the jackal) and the cat, a solitary animal which has never passed through the herd stage. The dog has a sense of duty beyond what is due to his offspring; when

he recognizes himself as part of a family or of a herd of sheep, he will protect them at the expense of his life. He has a sense of guilt when he fails in his duty, and will stay to receive his merited chiding. The cat has no sense of duty beyond that to her own offspring or, rarely, to her adopted offspring.

In Kipling's stories are examples of this difference. "The cat that walked by himself and all places were alike to him" is an animal that, outside of family duties, is solitary. The wolf represents the herd animal:

Now this is the Law of the Jungle — as old and as true as the sky;
And the Wolf that shall keep it may prosper, but the Wolf that shall break it must die.
As the creeper that girdles the tree-trunk the Law runneth forward and back —
For the strength of the Pack is the Wolf, and the strength of the Wolf is the Pack.[1]

Thus the association of animals into a group (herd, pack, etc.) has resulted in many instinctive reactions in each individual of the group. These reactions, known collectively as the herd impulse, represent a great advance over the parental impulse. The individuals of the herd have, besides the care of their own young during infancy, the continued care of all members of the herd.

Types of herd impulse. The herd impulse is expressed mainly in three different ways: (1) the aggressive impulse, in a grouping of animals primarily for the capture of prey (example, the wolf pack); (2) the protective impulse, in an association of individuals principally for the protection of self and young (examples, the sheep, ox, and horse); (3) the socialized impulse, in a union of individuals chiefly for protection, at times for aggression, but always uniting more or less to form some structure for the common good (examples, the honeybee and man). A simple form of this type is seen in the sociable weaver bird of South Africa. Here all individuals

[1] From Rudyard Kipling's "The Second Jungle Book." Doubleday, Doran & Company, Inc. Copyright, in 1897, by Rudyard Kipling.

of a colony unite in building a large umbrella-like structure, pendent from the limb of a tree. This is a protection against their worst enemy, the snake. Each pair of birds then builds its own nest attached to the underside of this structure. The hornets are other well-known examples of the socialized protective type. At times also the ants and man represent the socialized aggressive type. The ants go on raiding excursions for slaves, while in man this aggressive quality is too well known to need comment.

The herd impulse in man. Such mental reactions as the eight mentioned above would be impressed upon succeeding generations of primates and earlier social animals through the successful survival of the individuals exhibiting them. Today, through natural inheritance, we find them impressed upon man's body. In man we recognize the herd impulse in many characteristic reactions. (1) Man, like the lower animals, is sensitive to the voice of the herd; it can inhibit or stimulate conduct, courage, energy, endurance. Its effect in increasing energy and endurance is the basis of the cheering sections in sports. (2) He is subject to the passions of the pack, as is seen in mob violence or in heresy spasms. In 1692 a sudden delusion seized the people of Salem, Massachusetts, that certain persons were in league with evil spirits, and before reason returned they had hanged nineteen persons. Reason belongs to the individual man. The passions of the pack belong to the group, an inheritance from prehuman ancestors. (3) He is remarkably susceptible to leadership, as is seen in his relation to political demagogues or schoolboy chiefs. (4) He has recognition marks in peculiarities of speech and in ideas. (5) The herd (that is, other members of his kind) is his normal environment. He is, as a rule, fearful of solitude, physical and mental. (6) Originality in conduct is suppressed; it is looked upon with suspicion and is eradicated with ridicule or suppression. (Note the fixed limits of the time during which a man may wear a straw hat.) Hence what the majority say or do in any country or any generation is considered

right. Like Kipling's Bandar-log, "We all say so, and so it must be true." Man follows the style in ideas as well as in dress. (7) His mental reactions are fixed by the things with which his senses usually come in contact, and by the things approved by those individuals with whom he most associates, or by the literature that he reads. If we are reared in a family or community with a strong Republican political "faith," we shall, for many years at least, combat any Democratic "heresy" without investigation. If our parents and the majority of our neighbors believe that man is the result of a separate special creation, the thought that he may possibly be related by ancestry to the lower animals is repugnant and is naturally combated without a direct investigation of the evidence. The shock of displeasure that we feel upon hearing or seeing something very different from the usual has nothing to do with the intellect. It is simply an emotional reaction that we share with the lower animals. A horse will shy at an unfamiliar object by the side of the road; a dog will bark at a stranger; yet the object may make the road safer for travel and the stranger may be a better man than the master whom the dog had expected to greet. As soon, however, as we feel this displeasure, this unaccustomed nervous reaction, we strive to prove to ourselves that our feelings are reasonable and right. This is an unconscious attempt to justify our acceptance of the decision of our lower instinctive impulses through appeal to our later-developed reason.

As the lower social animals strive to keep the herd intact by excluding all who differ from themselves, so does man. The Puritans in Massachusetts strove to maintain the integrity of their particular herd by various peculiar public devices, — stocks for the wine-bibber, binding and gagging for the scold, the pillory for the swearer or breaker of the Sabbath, and ducking or banishment for those speaking against the church and government.

Communism and individualism. It appears that the arthropods and the vertebrates accent different aspects of the herd

impulse (Fig. 28, p. 231). Since the arthropods have evolved a completely enveloping external skeleton, they can grow only through a series of molts, continuing as long as growth continues. The adult lobster and the crayfish molt about once each year, and oftener during the rapid growth of youth. Among the higher insects growth takes place only during the larval stage; after the adult hatches from the pupa, or chrysalis, there is no more growth or consequent molting. This necessity for the expenditure of much energy in the development of each new skeleton keeps the arthropods small in size, and the nerve centers accordingly remain small. The result is that the groups developed within the arthropod phylum are much more like the multicellular animal than are the groups (herds etc.) of the vertebrates. There are groups, for example, among the ants and bees, the wasps and termites, in each of which occur sexual individuals, neuter workers, and soldiers, each different in form from the other. This division corresponds somewhat to the subdivision of labor in the many-celled animal into cells restricted in function to reproduction, cells grouped into organs for the gathering and digestion of food, and cells arranged at the surface of the body (in the form of skin) for protection.

The aggregation of the cells to form an individual many-celled animal is an example of pure communism, where each works only for the welfare of the whole. Each cell has a definite function to perform, and all its descendants perform the same function, in a perfect caste system. A bee swarm or a termite colony is the nearest approach to this state that we have among the groupings (herds) of many-celled animals. Such a primitive arrangement is possible, apparently because of the small size of the brain (supra-œsophageal ganglion). Thus, because of the small brain and the external skeleton of chitin, which furnishes material for the rapid evolution of implements for particular functions, actions are governed by instinct rather than by intellect. Hence some insects have been able to evolve into perfect communistic colonies (Fig. 28).

The large body of the vertebrate, made possible by the internal skeleton, results in a larger brain. Since the external projections, or limbs, of the body must be attached to the internal skeleton, and are hence limited to those which the ancestral fish had evolved, they must perform all the much more varied functions of the higher vertebrate animal. The performance of many different functions with the same instrument means the increased use of the brain, and hence we see in vertebrates a greater and greater development of intellect. It follows that groupings within the vertebrate line cannot become perfect examples of communism. The large brain entails individual thinking, and this is apparently essential to progress, for new ideas in invention, art, philosophy, etc. arise in individual brains. A certain amount of communism is, however, necessary for the protection of the entire group and of each individual within it. The higher races of man welcome group oversight of food, water, sewage, etc. The result is a struggle in the vertebrate groupings between communism for protection and individualism for progress. The necessary attempt to balance these two phases of herd life leads to increasing intellectual and social development.

As one studies a series of animals or plants one notes the twofold aspect of the change from lower to higher forms. These are differentiation and integration, — the tendency toward separation and individualism, and the tendency toward union and coöperation. Apparently they arise at the same time. In any description of evolving forms the former aspect is the more emphasized, since it can be studied in the dead body; yet the latter is essential, not only in coördinating all the bodily organs, so that they work together as a unit, but also in causing growth to take place in proper regions and in proper order. Every addition of new structures in an evolving series of plants or animals must be unified with the entire organism; otherwise death would result. Two important agents in this integration are the nerves and the products of internal secretions (hormones). Evolution is just

as fundamentally an organizing, integrating process as it is a differentiating process.

Competition within an organic whole does not usually mean combat to the death of one of the competitors. Frequently each is essential to the full completion of the other. The extensor and flexor muscles of an arm are opposed to each other in action and compete with each other for sustenance; yet the success of each of these antagonistic groups of muscles is dependent upon the success of the other, because they were developed, and do their work, as parts of a larger whole. The same is usually true of any two members of any organic system. (The Russian scientist, Peter Kropotkin, in "Mutual Aid as a Factor of Evolution," emphasizes this aspect of animal societies.) Those organisms are successful which modify their environments in such a way that each assists the other. The majority of the North American Indians, in the hunter stage of development, accepted their environment and struggled individually as far as those in the herd stage of development could do so. The European races, in the agricultural stage, coöperated in modifying their environment.

TOPICAL REVIEW

Instinct and instinctive impulses.
The two primary impulses.
The parental impulse:
  Length of infancy.
The herd impulse:
  Instinctive impulses to which gregariousness gives rise;
  Types of herd impulse;
  The herd impulse in man;
  Communism and individualism.

CHAPTER XXI

MAN'S CONTROL OF HIS EVOLUTION

Our present conception of the world and its life is of something dynamic, not static. The forces which affect the world and its inhabitants are being investigated and controlled. Diseases are no longer looked upon as arising from an offended deity. We have traveled far from the conception of the world depicted in "Œdipus," in which man was utterly at the mercy of a capricious God, where nothing that he willed to do could control or modify his fate. Man's knowledge of the sequence of cause and effect is being greatly broadened. The paleontologist has traced the stream of life (somewhat haltingly and interruptedly, but none the less progressively) from pre-Cambrian times through the millions of years to the present. The psychologist has not only traced our impulses, the basis of our mental life, back to their animal origins, but has indicated the way in which they may be sublimated and redirected to the future control of our evolution.

The development of the individual is dependent on the interaction of two sets of forces, the internal and the external, the former represented by the possibilities resident within the individual, the latter by the environment into which he is born and in which he lives. The internal forces, in other words, comprise man's physical, instinctive, mental, and spiritual inheritance; the external forces include his material environment and his social inheritance.

Comparison of modern man with his ancestors of the Cro-Magnon age reveals a pronounced similarity in shape of body and in brain capacity. It is apparent that physically the man of the upper Pleistocene of twenty thousand years ago was as highly evolved as is man of today; but a comparison of

the material environments of the two, and of the body of social traditions which formed for each his intellectual and moral environment, reveals an immeasurable difference. Man's tools are really extensions of his body, like the claws of a crab. He builds his house outside himself, not attached to himself, as do the snail and turtle. Thus he need not change physically to adapt himself to his changing environment. His brain and hand are the specialized adapting organs which relieve the rest of the body from the necessity of structural changes. Except for such slight variations as those due to climate it is possible that man has reached the limit of evolution as far as his body is concerned. But because he is man, possessing that imponderable something that distinguishes him from the highest of all other mammals, there are limitless possibilities of evolution before him. He alone of the primates is assuming an enlarging control of his environment, both physical and social. He alone, through his increasing knowledge of his physical body and of the subconscious and conscious forces in his mind, is learning how to control and direct his body and mind and their impulses. Because this increasing body of knowledge becomes part of the social environment of each succeeding generation, man through his knowledge and his ideals controls his future to a very large extent, and may endlessly modify his physical and social environment. He may modify the physical body of the future man by eugenics (race improvement through heredity) and by euthenics (race improvement through environment). He may sublimate his impulses and instincts and build up a social tradition of their control, and thus evolve an increasingly intelligent code of morals for the next generation.

CONTROL OF FORCES INHERITED THROUGH THE BODY

The body. The physical body is the instrument with which man must make contact with his world. If this instrument is imperfect in any way, he fails to that degree. A man cannot

do as good work with a poor knife as with a good one. It thus behooves mankind to see to it that each individual in the new generation is furnished with as good a body implement as possible. Hence, from the viewpoint of physical perfection, any defect which is passed from one individual to the next is to be deplored, and this is especially true when, as appears to be the rule, the heritable defect is incurable. It would thus naturally follow that any person who is insane, feeble-minded, or epileptic, or one with inherited blindness, deafness, or other very serious inherited defect, should not furnish bodies for the next generation. It is not only cruel to the offspring thus handicapped, but it is unjust to the normal individuals who must care for them. This is especially exemplified in the case of the feeble-minded and epileptic, as the other types cited are naturally so segregated that they have few offspring. Many examples have been described which well indicate this burden of the feeble-minded.

Emma W.'s grandfather was an alcoholic mental defective with a tubercular wife. They had two daughters and two sons, all mental defectives. Her mother had children by three men, one of whom was a drunken epileptic mental defective; concerning the others there are no data. Of the eight children by these three men, Emma W. was a high-grade imbecile, and each of the others was mentally defective. Emma W. came to an almshouse in New York State because of her feeble-mindedness; the rest are still at large.

Another well-known example is the so-called Martin Kallikak of New Jersey, a name given for the printed accounts of his descendants. While a youth in the Revolutionary army he had a son by a pretty, feeble-minded girl, born months after the army had marched to other regions. He probably knew nothing of the birth, but the girl gave the child his father's name. Of the 480 known descendants of this boy only forty-six were normal; the rest were feeble-minded, criminals, prostitutes, degenerates, paupers, and vagrants. After the war was over Martin Kallikak returned

home and married a girl of fine character and marked intellectual ability. Of the 496 known descendants of this union all but three were notable assets to any national life. They included successful governors, senators, college teachers, doctors, lawyers, engineers, and business men. Of the three others two were alcoholic and one sexually immoral. This example illustrates well the cumulative effect of good as well as of bad inheritance.

A German family studied consisted of 834 known descendants of a drunken vagabond woman. Most of these were tramps, paupers, prostitutes, and criminals (some murderers). The cost in money to the Prussian state for the care of this woman and her descendants has been one million dollars.

As the cited examples appear to indicate, what is inherited is an unstable condition of the nervous system which may express itself in different individuals as epilepsy, alcoholism, insanity, etc. The question naturally arises, How far toward the abnormal the physical bodies of a nation's population should be permitted to vary? Some very brilliant individuals, whose work the world could ill spare, have come from families in which insanity was hereditary. There are likewise many other heritable defects which, by the constant use of therapeutic aid, are counteracted in the individual but continue to be passed on to succeeding generations. Before the era of modern therapeutics these maladjusted individuals would have carried on a pitiful existence and left children in a somewhat worse state until that line became extinct. To what extent, if any, would the race suffer if none of these physically imperfect individuals had children? Kindness and justice alike urge us to give only such bodies to the next generation as they can use for the maintenance of a normal, healthy, helpful, and happy life. In order finally to attain this end, however, a much broader and deeper knowledge, not only of eugenics but also of euthenics, is necessary, and the development and spread of this knowledge should become an important force in man's social evolution.

Impulses and instincts. The instinctive reactions inherited through long ages of constant need naturally possess a tremendous momentum. They become forces of great import in man's life. The impulses connected with self-preservation and reproduction, for example, which in the lower organisms are the elevating forces that pull them up against matter, become in man forces which he must struggle to control. He may not suppress them, for they are essential to the life of the individual and the continuance of the human race. He must sublimate them, that is, turn their momentum into avenues socially useful. Man does not get rid of fire because it is frequently very destructive; by controlling it he turns the force into lines that contribute to his advancement. In "The New Psychology and the Teacher" Dr. H. C. Miller speaks of sublimation as the indirect expression of an instinctive emotion in some cognate manner that is socially useful. It involves directed restraint and control, but not repression. It releases psychic energy by the indirect expression of the primitive impulse.

In man primitive impulses are being constantly directed into higher channels. He sees something he wishes; the primitive impulse is to take it, — to steal it. But the recognition that he is an integral part of human society makes him do something useful in return for it. He knows that he must earn it. He learns, likewise, to control the reproductive impulse, to express it in creative activities, — in art, in science, and in business.

The impulses of self-preservation and reproduction, and the later-evolved parental and herd impulses, inherited with our body from brute ancestors, are forces with which man must continually reckon, and which, if he is to control his social evolution, he must continually guide into socially useful channels. A child should pass naturally from his intense individualism into consciousness of the rights of the herd; but if his parents and teachers are constantly telling him that he is different from others, — bad, always doing the wrong

thing, — it is likely that he will become an incorrigible, an individual against society, because society failed to make him a part of itself at the beginning. Of the prisoners in the Charlestown (Massachusetts) prison in 1921, Dr. Stearns showed 50 per cent to be the victims of the acquisitive instinct; 25 per cent, of the pugnacious instinct; and 25 per cent, of perverted sex instinct. The acquisitive and pugnacious instincts are two phases of the impulse of self-preservation. Thus 75 per cent of the prisoners were here because the impulse of self-preservation, which in all its aspects is perfectly right for unsocial animals, had not been acted upon by the later-acquired herd impulse. The tracing back of these criminals showed that they usually started in the home as children difficult to deal with, then became incorrigible, and hence were sent to delinquent schools, next to reformatories, and finally to prison. The whole life of the child tended thus to represent it to itself as one apart from the herd, — just the reverse of what it should have been. Such men remain, because of their education, at the mercy of their primitive impelling tendencies, unmodified even by the herd impulse, and hence become a social menace. Each individual must be led to realize that he is a necessary part of human society. This means the transformation of the herd impulse into the herd motive. It is the difference between being unconsciously impelled by an impulse and consciously acting on a motive. The herd impulse transformed into an ideal leads to the effective recognition by the individual that all his potentialities, spiritual, mental, or physical, are held in trust for the herd. This identification with the collective aim of society is the underlying principle of sublimation.

CONTROL OF FORCES INHERITED THROUGH THE ENVIRONMENT

The physical environment. Man's control of his physical environment is getting more and more complete. With his partial conquest of disease, and with a better knowledge of

foods, house construction, and heating, he has established a large measure of control over his physical surroundings. But the present climatic environment which man has inherited from the past constitutes a force with which he must also reckon. Whether he lives in a region where climatic contrasts give him a high level of energy or where the opposite is true, his habitat is a force which must be considered and which is as yet beyond his control. Man has advanced farther, however, in the power to regulate his physical surroundings than in the control of his social environment.

The social environment. Man's social environment includes not only all that his immediate environment (parents, community, school, and church) has retained from the accumulation of the past, but also what the rest of humanity has retained. Since each individual man is connected with a nation, any forces which affect the relationship of this affect the individual. Some of the forces resulting from this knowledge stored up from the past affect nations in an integrative, unifying way, while others are disruptive.

Physical science is the most positive and wide-reaching of all the integrative forces among nations. No matter how diverse in many respects, and even antagonistic, the nations may be, the steam engine, the telegraph, the prediction of eclipses, and the control of epidemic disease are the same to all. All who would reap the benefits of these must conform to the principles underlying them, regardless of national idiosyncrasies. Commerce and finance constitute another great integrative force between nations, but it is probably less potent than science, because even at its best the character of competition is inevitable, and this tends to bring in an alienating factor. Religion is a powerful force which is at times disruptive, at others integrative. It cuts across race, language, and political affiliation. In its integrative aspect this is easily seen today in such bodies as the Mohammedan and Catholic churches, and in the Young Men's Christian Association. The modern labor movement is another force in international civilization, appar-

ently tending toward both differentiation and integration. It thus includes both factors that must be present in any stable evolution. The unifying force in a common language is well known, and when there is added to this the common interests within a nation, it is doubly strong. This is well exemplified in the various nations in the Americas, made up of individuals from dozens of nations, each with its own language.

It is distinctively human that the imponderables form the most important groups of forces that beset man from the outer world, — the ideals of the family into which he is born, the moral standards of the society in which he moves, the state of progress of the government of which he is a member, — in short, the education which he receives. Though the effects of this set of forces are not inherited with the body and its accompanying instincts, yet each individual after birth becomes heir to the products of the past evolution of his race. Herein lie great possibilities. The world into which future generations are to be born can be infinitely readjusted. By virtue of being born a member of a herd each animal is heir to a smaller or larger body of tradition — his social inheritance — that has been built up by the accumulated experience of the herd. By virtue of being born a man he is self-conscious and possesses reason, and hence need not, like the animals below him, be wholly at the mercy of his inherited impulses and the inherited body of social experience. On the one hand, he may control or sublimate the impulses; on the other hand, he may add his own experience to that which he inherits from his herd, and hence may consciously shape to some degree the body of social experience (that is, the social inheritance) which is handed on to the next generation.

SUMMARY AND DEDUCTIONS

The flow of evolving energy from early pre-Cambrian times to the present expresses itself through increasingly complex forms until individualization is attained in man with con-

sciousness of self. This energy expresses itself through each individual organism in the process of living. Certain acts involved in this process of living are performed so frequently and are so essential to the life of the race that they have become impressed upon the nerve cells as natural impulses and instincts. Two groups of these impulses, which have characterized life ever since its inception upon earth many millions of years ago, are those concerned with self-preservation and reproduction. Without these life could not have persisted. Later, during the Mesozoic, arose the parental impulse, and still later, during the early Cenozoic, the herd impulse. As soon as an animal becomes a social organism all its acts, even such individualistic primitive impulses as those connected with self-preservation, become social forces; for as soon as individuals unite into a group, the acts of each affect all. A man may drink alcohol as an individual act, but in his family or when handling an automobile the social aspects of this act are seen.

Man is thus endowed with tendencies toward a definite expression of his energies, that is, with impulses and instincts inherited from his brute forbears; but in addition he bears within himself powers, attained with his manhood, which are capable of controlling and guiding the expression of these tendencies. Below man, life is very largely at the mercy of its impulses, but with the incoming of self-consciousness and the power of abstract reasoning man can scrutinize these impulses and decide how to modify their expression. He may not destroy these forces which he has inherited with his body, for they are essential to his individual life and the continuance of the race. He must turn them into avenues socially useful, or the human race will cease to advance and finally to exist.

It is especially during adolescence, the time of sexual maturing, that the individual enters the larger life of the human race. It is especially then that the boy and girl feel these old phyletic impulses urging them to express in their own persons the myriad activities which have characterized

the race in the long ages of its development. The youth is at this time least understood by his elders, and he least understands his own desires and actions; for the development of new neural pathways and the flooding of the system with new catalysts call out for the first time in his body these old race impulses. This is especially the time of self-sacrificing tendencies, — a time of conflict between the phyletically older individualism and the newer emotional sensitiveness arising from the maturing of the distinctly human instincts. This growing consciousness of a wish to serve mankind is shown in the graduating addresses of any high school. The adolescent time of the girl is much more severe than that of the boy, for she must achieve a more complete subordination of the individualistic tendencies.

If the energy of sexual creation be suppressed, it may, as Freud has shown, be burned downward, producing hysteria, or be transmitted into daydreams; normally, however, it is transmitted into other creative impulses, as in science, art, music, literature, and the everyday work of the world. Although these impulses originate in the subconscious, the direction taken is open to conscious control.

The entire behavior of each invertebrate animal and of many of the lower vertebrates is governed by the two primary impulses alone, — self-preservation and reproduction. When parental impulse appears, it becomes, in its best expression, dominant. When, in the cat, for example, the offspring are small, the mother will forego her own preservation for the sake of her young. Again, when the herd impulse appears, it takes precedence over the others. In wild cattle the preservation of the herd is more important than the preservation of one adult or one young.

Naturally the next step is that man, with his higher attributes of self-consciousness and his power of abstract reasoning, is coming to a gradual realization of the oneness of the human race, of the brotherhood of man, as well as his kinship with and hence responsibility to the lower forms of life. This en-

larging conception of brotherhood is, as we have seen, a force established with the initiation of life upon earth. This force has existed throughout the subsequent millions of years, and is one with which man must reckon if he would continue to live upon earth.

In the very impulses which he inherits from his brute ancestors man possesses forces which he can control for the advancement of the race. Because of this inheritance he views with suspicion pronounced originality of conduct. What the majority say or do is considered right, not because each has reasoned it out for himself, but because the fear of originality of conduct is impressed into the very nerve cells of man's body through long ages of inheritance. It was necessary to the preservation of the herd. This is not only a tremendous factor in the stability of any social structure, such as society and government, but a barrier to rapid change. We recognize that changes may be brought about only slowly and by process of education. The essence of education is self-discovery and self-control coupled with an enlarging vision. The education of the future should enlarge our knowledge of the factors of man's inheritance and show them as forces which, to some extent at least, can be controlled.

TOPICAL REVIEW

Control of forces inherited through the body:
  The body;
  Impulses and instincts.
Control of forces inherited through the environment:
  The physical environment;
  The social environment.
Summary and deductions.

CHAPTER XXII

EVOLUTION OF SERVICE

Service is essential to life upon earth. If no help were given to others all life would become extinct within a single generation. This service is of course entirely compulsory in all plants and in the majority of animals, but in the higher animals a growing amount of volition enters certain kinds of acts.

Compulsory service. *Examples.* A most important type of compulsory service from an evolutionary point of view is the storage of food for the developing young. This is seen typically in the yolk mass surrounding the embryo in the bird's egg and in the starch nutriment inclosing the very young wheat stalk or oak tree.

Another type of compulsory service, especially common in plants, is the yielding of the parent's life in the production of young. We see this in the majority of herbs and grains,— the radish, cabbage, wheat, and oats, all must give their life to produce seeds. Though this manner of producing offspring is not so characteristic of animals, yet it occurs among insects, corals, and many other groups.

When an animal becomes the food of another, he performs a service, even though it be involuntary. J. G. Holland expresses the universality of this form of compulsory service.

> Life evermore is fed by death,
> In earth and sea and sky;
> And, that a rose may breathe its breath,
> Something must die.
>
> The milk-haired heifer's life must pass
> That it may fill your own,
> As passed the sweet life of the grass
> She fed upon.[1]

[1] From J. G. Holland's "Bitter-Sweet." Charles Scribner's Sons.

Evolution of compulsory service. It is to this type of service that all animal life and all higher forms of vegetation are due. That it has existed upon the earth from the early times of earth history to the present is proved not only by the fact that all animals at present live upon other organisms, but by the occurrence, in the rocks of all ages, of fossil remains having teeth, claws, tentacles, and other food-procuring devices. It has, moreover, gradually increased in amount and effectiveness from ancient to modern times.

The plants (bacteria, blue-green algæ, etc.) in existence during the early history of the earth (the pre-Cambrian and lower Paleozoic) were those that multiply by spores. A spore is a single, usually microscopic, cell developed and set apart by the parent to carry on the race. These minute bodies stand but little chance of developing into adult plants. There is no stored-up nourishment upon which they may draw until they develop to a size at which they have a fair chance of survival.

A few of the animals living during these times of earth history similarly reproduced their kind by means of spores, but in most of the groups reproduction was by the union of two kinds of cells, the large female cells and the small male ones. The union of two of these different kinds of cells was necessary to produce a fertilized cell which alone could develop into an adult form like the parent. These reproductive elements, the male and female cells, were thrown by the parents into the water, where, if a union happened to take place, the beginning of a new individual resulted, but otherwise they died. This method of chance fertilization characterized nearly all groups from the one-celled protozoan up through the pelecypods. All animals at this time were water dwellers. They were of a low order of development and could consequently give little aid to their offspring.

By the mid and upper Paleozoic, plants and animals had evolved to such a degree that they could furnish nutriment for the growing embryo. Small seeds were present in the seed ferns, primitive cycads, and conifers. Among animals a large

amount of yolk surrounded the fertilized cell in the gastropods and cephalopods and in various arthropods, fish, amphibians, and reptiles. (This higher type of compulsory service was already active during the lower Paleozoic among the higher mollusks and the primitive arthropods, but in these the amount of yolk stored for each fertilized cell was small.) In the majority of these animals a surrounding tough capsule protected the developing embryo from many of its enemies, while the inclosed yolk insured sufficient food for considerable growth, so that upon leaving the capsule it would have a better chance for survival to maturity.

With the evolution, in the Mesozoic Era, of the higher seed plants, insects, and fish, and of the most primitive birds and mammals, the service that each generation rendered to the succeeding was of a higher grade. The higher seed plants, typified by the oak and hickory, furnished better seed protection and usually a larger amount of embryonic nutriment than did the primitive seed plants of the upper Paleozoic. Furthermore, the seed was supported by the parent until the fertilized cell had developed into an embryo, — a miniature plant. Some of the Mesozoic mammals, allied to the existing monotremes, probably, like these, laid eggs, and after hatching suckled the young. Others more nearly related to the kangaroos and insectivores were, in all probability, like their modern representatives, forced to protect and nourish the growing embryo within the body until it was well developed. After birth they continued this care by nursing the young.

During the Cenozoic appeared still higher forms of compulsory service in plants. The production of conspicuous flowers, of nectar, and of other devices for the perpetuation of species of plants originated mostly during the Cenozoic, though some of these devices were initiated in the Mesozoic. In animals the advance is seen rather in the accentuation of a higher type, that of instinctive service.

There is thus seen to be a very great advance in the amount and kind of compulsory service given to offspring by plants

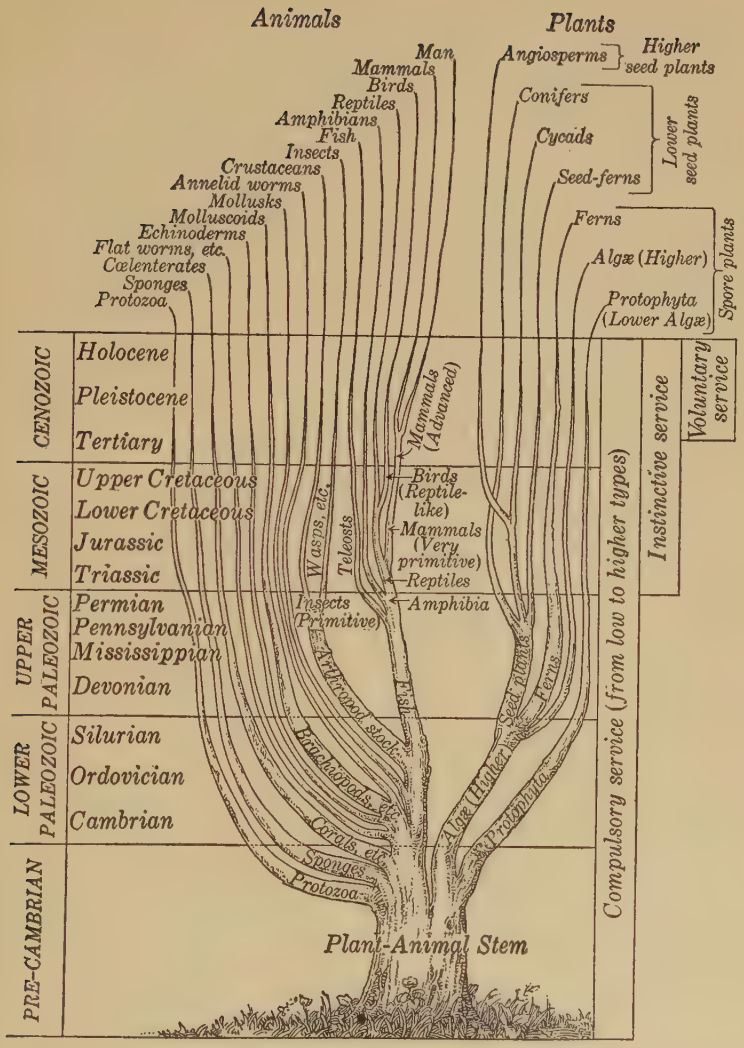


Fig. 27. Evolution of service

and animals from the inception of life upon earth during the Archeozoic Era to the present.

Instinctive service. In all the acts so far considered the plant or animal must perform the service to its offspring, — the reproductive cell must be developed and must be surrounded with nourishment, and the higher mammals must similarly nourish the young within the body and after birth secrete milk for a certain length of time. In addition to these services that each species exacts of its members there are other acts performed by the parents after the egg is laid or the young is born which cannot be so definitely labeled compulsory. The behavior of birds in the hatching of eggs and in the later feeding of the young fledglings is a different sort of service from the development of the nutriment about the fertilized cell. The latter must be done, in one fixed way by all; the former may not be done at all, as in the case of the cuckoo, though the majority of birds perform these acts. The performance, however, varies greatly among individuals of the same species.

Most robins, for example, will desert their nests upon a distant approach of danger. A few will remain upon the unhatched eggs, pecking at the approaching human hand, if that is the danger. A few sunfish will fight courageously to protect their rude nests. In the solitary wasps, typified by Ammophila, Mr. and Mrs. Peckham, in "Wasps, Social and Solitary," have shown that individuals of the same species differ greatly in the amount of food they furnish their young. Some are good providers, others poor. Some also are exact and precise in all their movements; others are very negligent and disorderly, leaving their offspring less effectively protected in many ways. In all such cases some individuals may be said to have a greater amount of protective instinct than their fellows.

The most important characteristic distinguishing instinctive service from compulsory service is that in the former the individual may give less or more than the average for that

species. It is partly an individual affair, and in this it verges toward voluntary service.

Instinctive service probably arose early in the Mesozoic; for the incoming of mammals, birds, higher reptiles, teleost fish, and wasps at this time was apparently accompanied by a certain amount of such service. The mammals, while suckling their young, would tend to fight off enemies and also provide more or less solid food for them. The same service would be rendered by birds in hatching their eggs and feeding the young. The teleost order of fishes includes the majority of our living fish, — those in which the parental impulse is best developed. The Mesozoic wasps probably gave to their young at least a beginning of that instinctive service which characterizes their modern representatives. Later, during the Cenozoic Era, the herd impulse was present in many of the more highly evolved mammals, such as the carnivore, rodent, and hoofed orders, and hence there must have been many expressions of instinctive service somewhat comparable to that which we see in herds today.

Voluntary service. Instinctive reaction to the needs of the next generation is service intermediate between that which is compulsory and that which is voluntary. In regard to the instinct of helpfulness to offspring, the difference between individuals of the same species appears to be a step in the direction of voluntary service. In humanity at least the latter state has been attained. Man's actions vary from instinctive acts similar to those cited, as a mother's rushing into the street to save her child in danger of being run over, to those following upon conscious deliberation, — true voluntary service.

The human species displays all these three types of service. The unborn young must be given intrauterine nourishment. Through parental and herd impulses the individual yields instinctive service to offspring and others. After deliberate thinking he may perform additional acts of service which are thus entirely voluntary. The dividing line between instinctive and voluntary acts is, however, very obscure.

While the difficulty of defining many human acts as either instinctive or voluntary is great, it is even more so in the case of animals below man. Students of animal behavior are not agreed as to the amount of reason existing among these animals, and reason is the basis of volition. Many are agreed, however, that the highest groups of animals, as the dog, cat, horse, and elephant, possess a certain amount of reason and thus the basis for voluntary service. These animals came into existence in the later Cenozoic, as did man. In man voluntary service advanced at first slowly, and for a long time was doubtless limited to the family; gradually it extended to other members of the clan and nation, and to those speaking the same language, and finally included even those of different tongues.

Summary. Thus we see that the development of life upon this earth was due to service, — that without such service no higher forms of life could have evolved. Animals can live only through the aid of other animals or of plants. Both animals and plants are compelled to give of their strength, and often life itself, in the production of young. As animals and plants became more highly evolved they developed a higher type of service, — that of furnishing more nourishment and better protection to their offspring. Very gradually, side by side with the higher kinds of compulsory service, there was evolved an instinctive service in which the individual gave a variable amount of additional aid. This type increased in amount from primitive to more and more advanced grades of parental impulse, in which acts of service were at first entirely, and later largely, confined to the family. Thence through the herd impulse each animal aided in the well-being of the entire group. More and more in the higher animals this instinctive type of service tended toward the voluntary, so that at times it is impossible to say in which category it belongs.

The very long pre-Cambrian time and the early Paleozoic are characterized by low types of compulsory service; the later Paleozoic, Mesozoic, and Cenozoic display successively

higher and higher types in both plants and animals. Instinctive service of a low type was present in different groups of animals during the Mesozoic; it increased in amount and kind throughout the Cenozoic. The later Cenozoic stands especially for the greater and greater development of voluntary service. In the highest representatives of man today it overshadows in amount both instinctive and compulsory service.

It is undoubtedly true that this increasing service rendered by the successively higher forms of life has been one of the causal factors in the evolution of both plants and animals. Offspring that were fed and protected during even a part of their immature youth would be stronger and more apt to live to produce offspring in turn than would those lacking this care. Thus that plant or animal group in which each generation gave to offspring and to others of the herd more than they had received would stand the best chance of survival. This applies with especial force to man. Medical science has shown that with our present world-wide commerce the only way to compete successfully with the numerous disease germs and their carriers is through the willing coöperation of all nations and individuals.

When a plant or animal group takes more and more from others without giving additional service in return, it becomes a parasite, and parasites are not now (nor were they in the distant past) in evolving lines. Whether plant or animal, they are degenerate; the individuals become weaker and weaker, and finally the line ends in death. Thus the forms of life that give more than they receive are in the advance line of evolution.

TOPICAL REVIEW

Compulsory service:
  Examples of compulsory service;
  Evolution of compulsory service.
Instinctive service.
Voluntary service.
Summary.

CHAPTER XXIII

EXPANDING CONSCIOUSNESS

Life upon earth, as we have seen, has evolved from one-celled organisms through simple many-celled forms to the highly complicated plants and animals of today. Fortunately for our understanding of the reactions of the life of past ages, many forms closely allied to the ancient types still survive. The evolution of higher groups of animals brought them frequently into habitats not previously occupied, as fishes into streams, amphibians into swamps, reptiles upon dry land, or insects into the air, the lower groups continuing their much slower evolution in their old habitats. That a basic change in structure has occurred only at rare intervals is shown by the fact that all animals are classified in only twelve phyla. While the specific expression in individuals has been constantly changing, these modifications did not affect the ground plan of the group. Hence we assume that a study of the lives of the protozoans and bacteria of today yields us a general understanding of those one-celled organisms that lived ages ago. Since the corals of today secrete lime skeletons basically similar to those found through the geological eras, the other reactions of the living organisms were presumably likewise similar. In other words, the various characteristics of the individuals of a class of organisms living today should be basically similar to those of the individuals of the same class which lived during the past.

As has been noted, the animal line of evolution, as distinguished from that of the plants, emphasized motion, and the resulting freedom necessarily expressed itself in choice. Hence the long train of tropisms, reactions, instincts, and impulses with which life responds to its environment.

In man, response to environment, that is, his behavior, is correlated with a condition which is called consciousness. Since consciousness is a wholly subjective experience, its existence cannot be demonstrated objectively. The behavior of even the simplest animals, however, is of the character which we should expect if they had consciousness (of course, of a diffused and extremely generalized type; self-consciousness is not implied). H. S. Jennings, in his study, "The Behavior of the Lower Organisms," concludes that there are evidences, even in the Protozoa and Cœlenterata, of consciousness as manifested in perception, discrimination, and choice. There is perception in Amœba, as judged by its reaction to the thing we think it perceives. Paramœcium distinguishes acids from alkalis (that is, it reacts in a different manner to such differing stimuli), and all animal forms exercise choice in accepting some things and rejecting others. We, with our consciousness, can understand and explain why a Paramœcium should draw back from things that hurt it, and should attempt to move forward in various directions until it finds one in which conditions are favorable to it.

If, then, all animals possess consciousness, it is obvious that its increasing expansion would accompany the evolution of living forms. Increasingly refined instruments are provided for its manifestation in the development of the nervous systems of the various phyla and in the elaboration of hormones. It has been shown by psychological research that the basis of consciousness is hereditary and consists mainly of instinctive impulses which fall into four large groups: (1) that concerned with self-preservation (the ego complex), (2) that concerned with the preservation of the species (the sex, or reproductive, complex), and, growing out of these two, respectively, among higher animals, (3) the herd impulse and (4) the parental impulse. The evolution of consciousness is the history of these inherited instinctive mechanisms and their interaction with the impressions which are constantly flowing in upon an organism from its environment, whether natural or cultural.

EXPANDING CONSCIOUSNESS SEEN IN THE EVOLUTION OF THE IMPULSE OF SELF-PRESERVATION

The love of life is independent of reason and experience. It is spontaneous in every organism and leads it to avoid whatever interferes with its harmonious activity. In the very early days of earth history each individual animal was concerned only with its own preservation. It was impelled to give rise to offspring, but if some of these came in its way they would form part of the food of the parent. It was only gradually that offspring ceased to be looked upon as a possible source of food, and instead were regarded as something to be protected.

In the beginning life was confined to one-celled organisms. These had only themselves to preserve. Later there evolved the many-celled organism, in which thousands of cells united to form a single larger unit. In this case each cell aided in the preservation of the entire animal, that is, of the thousands of cells composing it. Much later some of the higher many-celled animals formed associations of individuals, in which each individual aided in the preservation of the entire group (Fig. 28).

Consciousness has here expanded from the individuality of the single cell, through that of the many-celled individual, to the enlarged sense of the unity of the group composed of many such multicellular individuals. The later-developed feeling of unity becomes partially or fully dominant over the preceding state. Frequently a many-celled animal has been known to gnaw off its leg caught in a trap, thus casting off many individual cells in order to give freedom to the more highly evolved larger unit, just as the many-celled individual man will amputate an arm or a leg, with its myriads of cells, to preserve the larger unity known as the man. The still later-developed herd, to maintain its unity, frequently casts out or even kills members that are detrimental to its well-being. The disturbing male is cast out of the herd, the nonworking drones

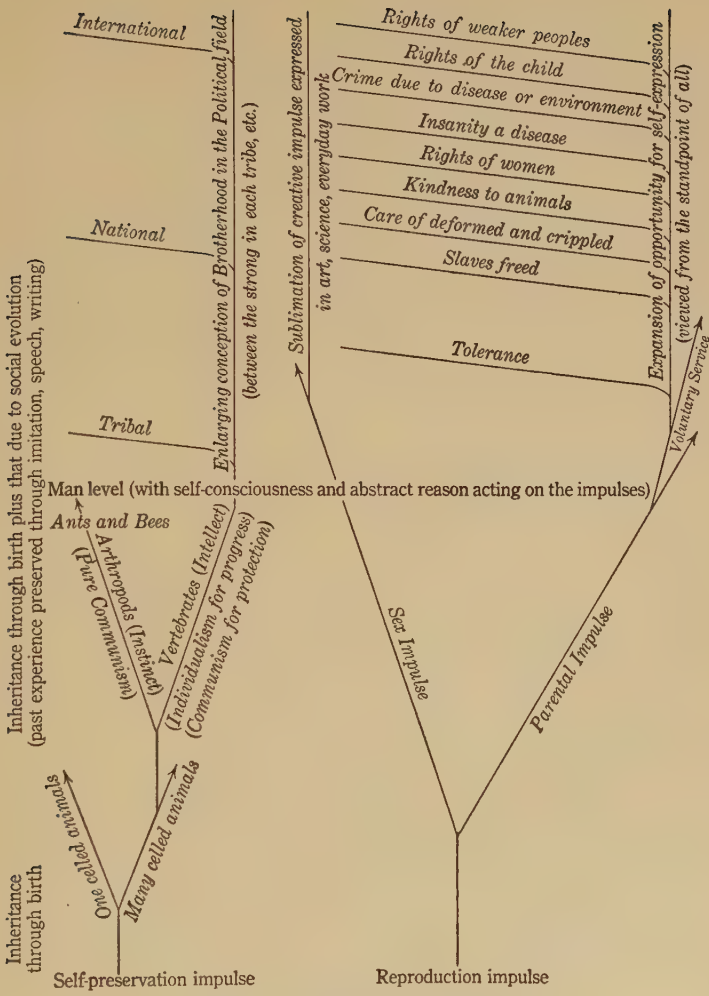


Fig. 28. Expanding consciousness

The expansion of the two impulses common to all life began with the earliest living forms upon earth in the Archeozoic Era and continues to the present. The incoming of man (man level) is in the upper Tertiary

are killed by the workers; among primitive men the offender was expelled from the tribe; today he is put into prison.

Later, as various human herds (tribes) became merged into a nation, consciousness of unity gradually expanded to include all members. We see this process at work today in the various countries of North and South America settled by English, Germans, French, Italians, Spanish, etc. In each of these countries, with lately developed geographic boundaries, various individuals with diverse national ties are gradually developing a unified national consciousness.

The next step, in process of development, is the growth of a unified international consciousness. The conquests of Alexander the Great, and more especially the later expansion of the Roman Empire, made of the Mediterranean world a temporary political unity. Such unities were, however, of necessity impermanent because a unified consciousness had not been established among the members; this can be developed only through the intimate knowledge and sympathy which printing, the common ability to read, and means of rapid communication can bring about.

Thus in the instinctive reaction of self-preservation, in obedience to which the strong survive (in whatever direction strength may lie), consciousness of self has expanded from the self-sufficient, minute, one-celled organism through the sense of unity of myriads of cells in the many-celled animal, through the enlarged unity of herd and tribe, and through the later-developed national consciousness, into the dawning sense of an international unity now evolving.

EXPANDING CONSCIOUSNESS SEEN IN THE EVOLUTION OF THE REPRODUCTIVE IMPULSE

Fossils show us that the earliest animals upon earth were such primitive forms as protozoans, sponges, and corals. These reproduce by giving off portions of themselves (minute cells) which can develop into other animals, their offspring.

By mid-Paleozoic time more complex forms had evolved, such as marine snails and primitive fish, which were capable of doing more for their offspring than could the simpler forms. These, instead of merely setting aside minute cells, surrounded each one of these with nourishment, — the yolk from which the young could derive material for growth for a time before they were set free to search for their own food. When, during the Mesozoic, still higher animals had come into existence, — primitive mammals, such as marsupials and insectivores, — the mother was impelled to nourish her offspring within herself until it had reached a form like the adult. Moreover, after birth she continued to feed it until it approached herself in size and was thus well prepared to protect itself and secure its own food. Still later, when the higher modern type of mammal had evolved in the Cenozoic, both parents aided in procuring solid food for the offspring; here belong such groups as the cat and dog families and the primate order.

This service to the next generation, and thus to the species, that life has from the beginning forced upon its members is carried on under the impetus of the sex impulse. This is primitively the urge to reproduce, but evolves imperceptibly into the parental impulse, under the momentum of which successively higher groups of animals give a successively higher degree of service to their young. The sex impulse enlarges not only into this feeling for offspring but into what McDougall terms the tender instinct, which holds the family together and forms the basis of much of the altruistic relation between individuals.

When certain representatives of the primate order became men, with the complete development of individual self-consciousness and a much higher degree of reason, they were in the group stage of development, as had been their ancestors since early Cenozoic. Thus man, beginning in this group stage, was endowed with all the herd-developed instincts. Among other instincts was his conviction of the right of might, —

the right of the strong to rule absolutely. Strong man dominated as does the strong male among mammals and birds today. The rest of the tribe, the women, slaves, defectives, and children, not being the equals of the man in brute force, were compelled to take subordinate positions. When later in each race the nation developed from the tribe, and private property took the place of that held in common, the selfish instinct inherited from the brute ancestor still prevailed, and the strongest males seized all they could for themselves and then made laws securing this property and honor to their descendants forever. The result was the inequality of classes which has characterized all nations.

Gradually, however, as the centuries passed, the sympathy growing out of the love of parents for their offspring began to enter these outlying fields of the weak and of those deviating from the type. In the recent past we note among mankind this enlarging conception of brotherhood in the freeing of slaves, the care given to the deformed and crippled, the growing equality of opportunity for the sexes, the recognition of insanity and crime as disease, and the growth in religious tolerance. The advent of Christianity gave an incalculable impetus to the spread of the spirit of compassion in the relation of man to man.

The buying, selling, and treatment of men, women, and children like cattle was practically universal throughout antiquity. Even in the time of Claudius, Gibbon estimates that the number of slaves in the entire Roman world was equal to that of the free. In early days all outside of the tribe were legitimate prey, and gradually, as the tribe expanded into the nation, none without it had rights. The ancient Egyptians, Babylonians, Assyrians, and Israelites confined their comparatively high morality to themselves; those with whom they fought had no rights. There was no protest, even from philosophers, to the practice of Alexander the Great of killing the men in the cities taken by assault and selling the women and children as slaves. Gradually among the ancient Greek states there developed a tendency to limit the enslave-

ment of conquered nations to non-Greeks, while Rome definitely limited its conquered slaves to non-Romans. This important difference in early times between those within and those without the fold is preserved in many paired words, such as *Greek* and *barbarian, bond* and *free, patrician* and *plebeian, Jew* and *Gentile,* and, even in later days, *Christian* and *pagan, noble* and *churl.* Upon the incoming of such religions as Christianity and Mohammedanism, trading in slaves gradually became limited to non-believers. Our word *slave* bears witness to the fact that up to the eleventh century, which saw the evangelization of Russia, the slave class in Europe was made up of Slavs, then pagans. Christian captives were merely held for ransom; still later in the seventeenth and eighteenth centuries exchange of prisoners grew to be the practice. The enslavement of negroes continued, however, down to the nineteenth century. England freed her colonial slaves in 1833, France in 1848, and Holland in 1863; in the United States the slaves were freed in 1862–1865.

Defectives among the ancients had, as a rule, no rights, and this has continued almost to modern times. Throughout England and the rest of Europe a hundred years ago the idiot and malformed were exhibited to afford amusement to people. Today the sight of such defectives usually brings a feeling of pity. Institutions have been established for the care and education of the malformed, so that they may lead independent, useful lives.

Throughout the Middle Ages in Europe the insane were supposed to be inhabited by evil spirits. They were hence outside the pale of charity and were often subjected to the most cruel treatment. Today we know that this state is due to some defect in the physical body, and so some are cured and lead normal lives, while others are treated as sick persons.

Pike, in his "History of Crime in England," has shown that in pre-Norman England men branded on the forehead, or without hands, feet, tongues, eyes, ears, nose, lips, or scalps, lived as examples of the danger which attended the com-

mission of petty crimes. The same was true throughout Europe, with practically no change from ancient savagery. Such, too, was the common practice of the ancient Egyptians, Babylonians, and Assyrians. In 1764 the Italian jurist Beccaria, through the publishing of his "Essay on Crimes and Punishments," set going the changes which have resulted in the present conception of crime. He held that the effect of cruel punishments is to increase crime by hardening the sensibilities of the people. He did much to abolish the physical torture which was then part of judicial proceedings. John Howard of England carried this reform forward so that gradually prisons were transformed from hells to hospitals for the development of self-respecting manhood.

We note among various conquering nations of antiquity a growing tendency to permit the exercise of any religion so long as it was not detrimental to the stability of the state. This was especially true of Rome. Lecky calls tolerance "the supreme attainment of Roman civilization." Later there was a lapse in this respect in both Christian and Mohammedan countries. Both held that all knowledge necessary for belief and action was included in their respective theologies, and hence that whatever was not included, according to the interpretation of the leaders of the time, was wrong. Since the fifteenth century, however, there has been a continued growth in tolerance in Christian countries, — a feeling that I should grant to my neighbor's belief in religion, education, etc. the same respect that I wish him to grant to mine.

Polygamy was the common practice of antiquity, — the rule of the strong male. Wives were usually considered as captives and prisoners. This state of things gradually gave place to monogamy, but even Aristotle, in so highly an advanced society as that of the Greek republics, agreed with the other Greeks in regarding women as unfit for freedom and political rights.

There is a growing recognition, by governments, of the fact that the obligations of the strong toward the weak are the same for nations as for individuals. The growth of this

belief has been especially rapid during the past century. Gradually the fate of the weaker race has changed. At first, to be weak meant extermination or slavery. Later, it implied reduction to the condition of a tributary. The Assyrians and other ancient nations forced all conquered peoples to pay them as much tribute as they possibly could. The magnificence of the Roman Empire was the result of an impoverishing exploitation of conquered nations. The next step in advance was reduction to commercial and industrial exploitation by the stronger people. The present idealistic conception, too often obscured and degraded, is to consider weaker nations as the beneficiaries of a benevolent, self-sacrificing service. It is the interpretation of the last step that is the question today. The important consideration is that, however slow the progress, the rights and freedom of conquered and weaker peoples are matters of intelligent concern to the dominant nations of the present time.

As has been noted, all the impulses which characterize life, and which each organism inherits as part of its bodily equipment, are centers of force. This psychic energy cannot be destroyed; it cannot be suppressed without injury; but it can be diverted into channels related to its original source. Each individual may, if he will, use such energy for socially desirable ends. The sex instinct, for example, may thus express itself largely in the care of offspring and in an increasingly widening range of sympathies. It may also provide the energy for the higher creative activities in art, science, philosophy, and the everyday work of the world (Fig. 28).

EXPANDING CONSCIOUSNESS SEEN IN THE INCREASING BODY OF RACE KNOWLEDGE

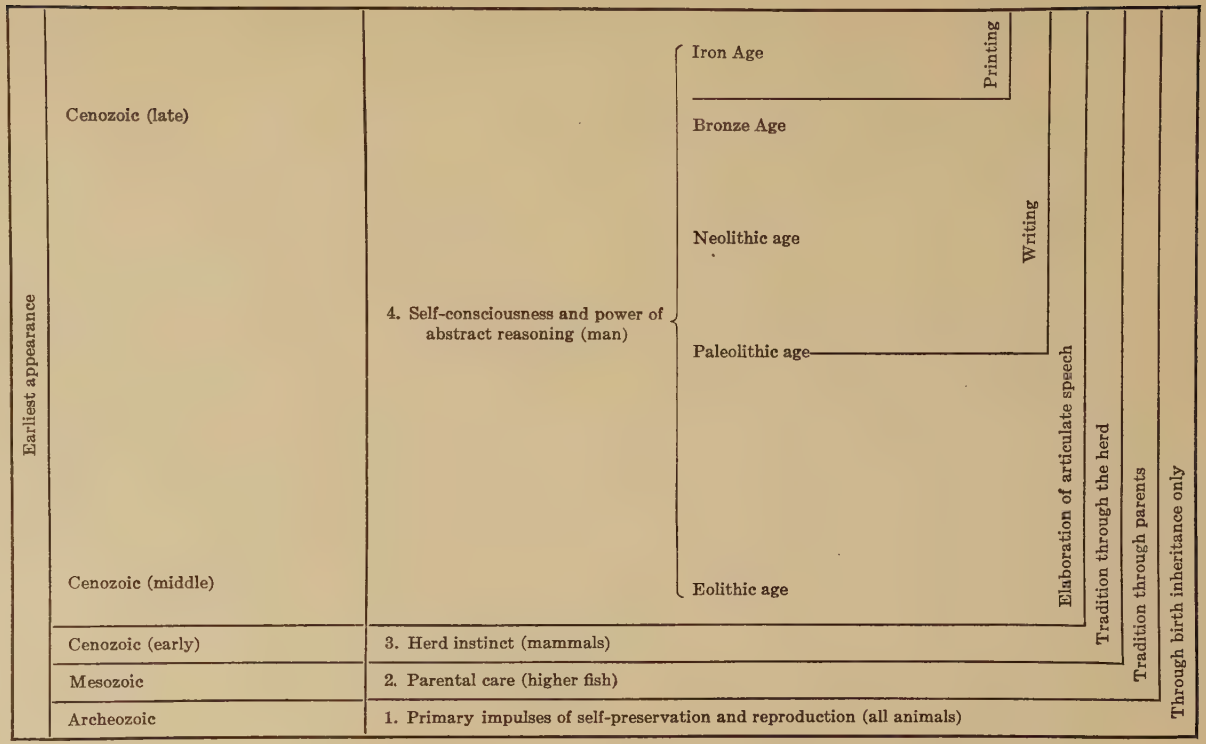
As we have seen, the only race knowledge inherited by the offspring of the earliest animals upon earth and for ages after was through birth. The protozoans, sponges, corals, worms, mollusks, etc. had still too simple a nervous organization to

be able to imitate those older individuals of the same species that happened to be near. Hence the minute amount learned during the lifetime of an individual could not be handed down to posterity. Gradually a higher nervous organization was evolved; with it appeared the care of offspring by parents. This is exemplified in a rudimentary way by the higher fish and the primitive mammals of the Mesozoic. Among these forms, imitation by offspring would pass on some of the reactions to environment learned by the parents during their individual lives. Later, in the early Cenozoic, with the appearance of mammals with a still higher nervous organization, the protective and aggressive type of herd instinct developed. In such herbivore and carnivore associations the offspring learn not only from parents but from the other members of the group, and a broader fund of race knowledge can be passed on. Thus, in addition to the gradual expansion of consciousness through the avenues of impulses and instincts, man's prehuman forbears constantly gained a larger control over their surroundings through the increasing mass of knowledge possessed by the herd as an inheritance from the past (Table XIII).

In brief, the lowest animals have only the knowledge (that is, ability, instinct) with which they are born. Each may add a very slight amount to his own inheritance during his life, but can teach nothing of what he learns to his offspring. With the appearance of parental instinct, however, and the consequent increasing care of the young, there enters the imitation of parent by offspring. Some knowledge is accordingly continued as a sort of tradition, in addition to that handed down through the generations by birth inheritance. With the forming of the herd the young, associating intimately and long with many more individuals than his parents, finds his imitative faculty still more expanded and the knowledge of his environment greatly broadened.

Mankind continues, at a more rapid rate, the social evolution begun by prehuman animals. Many of the stages in man's development survive today in various savage and

Table XIII. Evolution through the Increasing Body of Race Knowledge



semicivilized tribes; and fossil remains of early man and his art not only corroborate this evidence but show us the order in which the stages appeared. Earliest man is seen to have had very slight control over his surroundings. He made use of such sticks and stones as he found for his weapons and his tools. Later he very slowly learned to adapt to his own ends what he took from nature. He no longer used a simple log to cross a stream, but hollowed it out and formed a boat. Much later still, when his capabilities had expanded and his accumulated knowledge from the past had greatly increased, he became creative. He made cloth from plants, and bricks from clay. At first, after reaching this stage of expansion, he continued to use stone as his most efficient weapon and tool (the Neolithic age). Later he learned the use of metals.

This increasing control that man gains over his surroundings is accompanied by the increasingly rapid enlargement of knowledge from the past. Our prehuman ancestors had begun this line of advance, but reasoning man carried it forward with continually increasing rapidity. First came the elaboration of articulate speech, which gave to man such a vast enlargement of the power of coöperation. In the later Paleolithic, and especially with the Neolithic stage of development, writing was evolved. At first it was confined to picture writing (drawings of things and acts with dots and dashes for quantitative ideas, as with the American Indians); later it passed to the conventionalized form for more rapid use of stylus or brush, as with the Chinese. When adopted by conquerors or other alien peoples, it became a sign-for-a-sound writing. In one direction it became syllable writing, such as that of the Babylonians, Assyrians, and Chaldeans, which was developed from the ancient Sumerian picture writing; in another direction, letter writing, as of the Phœnicians, Greeks, Romans, and English, which may have developed from the picture writing of an unknown Mediterranean people.[1]

[1] An excellent discussion will be found in "A History of the Art of Writing," by W. A. Mason.

After the establishment of written records the mass of human tradition became more full and more exact. Man's thoughts could affect others at a distance, both in space and in time, and a consequent tremendous impetus was given to further development. Finally, with printing, writing became cheap and thus the common heritage of all mankind. If we compare the body of race knowledge of the ancient Egyptians or Sumerians with that of man today, we see how rapid and how great has been the increase. The consciousness of the man of today who has made even a small part of this fund his own is incomparably broader than that of man six thousand years ago, and a general intelligence has come to be the very breath of modern democracy.

TOPICAL REVIEW

Expanding consciousness seen in the evolution of the impulse of self-preservation.

Expanding consciousness seen in the evolution of the reproductive impulse.

Expanding consciousness seen in the increasing body of race knowledge.

APPENDIX

I

HISTORY OF THE CONCEPT OF EVOLUTION

The thought of each age is the foundation of that of the following age; that is, each man interprets the present in terms of his social inheritance. This social inheritance includes all that he learns from his parents, from schools, from every person and every thought that he comes in contact with. He can explain the unknown only in terms of his cultural environment. This must have been the case with man from the earliest ages to the present. As more knowledge was added to this inheritance by successive generations, explanations for the world and its phenomena naturally changed. All lines of human thought underwent constant modification. Hypotheses formulated to explain the origin of plants and animals have passed through three well-defined stages: special creation, catastrophism, and evolution. Since men today vary from individuals who have not studied any part of the increasing accumulation of facts that bear on this problem to those who spend their lives in research and experimentation along this line, the explanations given naturally vary and include all these stages.

SPECIAL CREATION

The question "What" is common to man and the animals below him. Is an object food? Is it dangerous? In time these questions lead naturally to a broader curiosity, and this into the distinctively human query "Why." Man is not satisfied without some explanation of the cause of all that he sees.

In the childhood of the race the origin of most things was unknown, and hence the only answer to the query was "It is due to the action of some being greater than man." Each species of plant and animal was a sudden creation of God. Since the Bible was an important part of the social inheritance of the Western world, it was natural that the Christian writers in the early days of the Church should

make use of the statements there given. Thus Father Suarez (1548–1617), a Spanish Jesuit priest, taught that the earth and every living species of plant and animal were made in six days of twenty-four hours each.

Keen observers, however, noting that certain groups of species resembled each other very closely, gradually came to the conclusion that each group (genus) was a separate creation. The most important of these thinkers was Linnæus (1707–1778), the father of the binomial nomenclature. In his system each animal and plant received two names, — a generic name, common to all species of the genus, and a specific name, peculiar to the species in question. This scheme proved a great stimulus to research in both living and fossil forms, for it made necessary a more careful examination of the organisms in order to note their resemblances and differences.

The term *special creation* has two distinct connotations. It may refer to the direct cause of the origin of the physical results, or to the ultimate cause, such as the origin of the laws under whose action the known results arise. It is the failure to recognize this distinction that has led to much of the controversy about evolution. Today almost everyone who has studied the evidence agrees that the direct cause of physical results is the action of natural laws. Among these evolutionists there are differences of opinion as to the ultimate cause.

CATASTROPHISM

As the fossil plants and animals were studied it became evident that the forms living in the distant past were entirely different from those living today. One of the earlier observers to notice this fact was Cuvier (1769–1832) while he was making a special study of the rocks around Paris. Since belief in such a catastrophe as Noah's flood was part of his social inheritance, he explained the change that he observed as due to a cataclysm which killed off the older forms and was followed by the creation of different ones. An increasing number of students brought rocks of different countries under close observation, and to them the evidence of a succession in time of different faunas and floras became clear. There was also evidence that such a succession appeared upon every continent. D'Orbigny (1802–1857) showed that there must have been twenty-seven catastrophes killing off all plants and animals, followed in turn by the creation of different organisms. The necessity of postulating so many world-wide cataclysms degraded man's conception

of the Creator and was one of the contributing factors leading to another interpretation of the facts in nature.

Detailed study of the fossil contents of successive rock beds disclosed the fact that all the forms did not disappear at the same time, — that the disappearance of species had been a gradual process, and that constantly, as some forms died off, others came into existence. It thus became apparent that there had been no great catastrophes, but only periods of increase and decrease in the death of species and of the incoming of new forms.

EVOLUTION

Quite early among the many interested in explaining the organic world surrounding them were some who postulated the theory that plants and animals had evolved. In these early days nothing was known of the evidence which the rocks of the earth had to offer along this line. The early observers noted especially the gradations between the living lower plants and animals and the higher ones, as well as the similarity in bodily form between the many different species included in the different larger groups which we now call phyla and classes. Many had noted the resemblances between the various species of echinoderms, between man and the four-footed beasts, etc.

Among the early Greeks some, like Empedocles (490–430 B. C.), taught that nature produced more and more perfect forms through chance, while Aristotle (384–322 B. C.) postulated an intelligence working through natural laws. Through his extensive studies of plant and animal forms, Aristotle saw in nature a gradation from plants to plantlike animals, to animals that could move, and finally to man.

Among the Romans, Lucretius (98–55 B. C.) held that wild animals preserved themselves but that domestic animals were preserved by man, — a fundamental observation. Cicero (106–43 B. C.) held that all living creatures exist for the sake of man, — an expression of the old, old belief that to the strongest belongs the earth and the fruits thereof.

The free speculations of the Greeks and their Roman disciples survived into the early centuries of the Christian Era, even among the early Fathers of the Church. St. Augustine (A. D. 354–430) distinctly rejected special creation. It was later that the doctrine of special creation became a dogma of orthodoxy and thus a principle of conservative science.

Throughout the medieval days of the Christian Era the belief in the sudden, supernatural creation of all things was so strongly held that few even thought of a different explanation, and these few were usually kept from expressing themselves by the influence of their associates. With the revival of the classical Greek learning in Europe from the fourteenth to the sixteenth century, however, public opinion very gradually became sufficiently tolerant to permit the expression of new and differing ideas. One of the first of the dissenters to see in evolution the key to the changes in plants and animals was Buffon (1707–1788), a French contemporary of Linnæus. Buffon emphasized the direct influence of climate, overcrowding, and other external conditions in producing new species.

The French zoölogist Lamarck (1744–1829), a contemporary of Cuvier, believed that the change in animals was due to the indirect influence of external conditions acting upon the internal structure through the nervous system. (In plants he agreed with Buffon that the action was direct.) The Buffonian and Lamarckian factors both assume the inheritance of acquired characters, — that new characteristics impressed upon an organism during its life can be transmitted to its offspring. This assumption has not yet been proved to the satisfaction of the majority of scientists. Lamarck denied catastrophism, — that such sudden changes occur in organic life.

Very gradually, through the work of many specialists, knowledge had been increasing in zoölogy and botany, in comparative anatomy, paleontology, embryology, and geographic distribution. Each generation had more facts than the preceding upon which to base its theories. It was into such a social heritage of many facts and ideas and of freedom of thought that Charles Darwin (1809–1882) was born. To this heritage of facts Darwin contributed many others through his careful observations. He was more successful than the majority of writers in making theory subservient to fact. The central thought of his writings is natural selection, the selection by nature of successive, slight, favorable, chance variations. This he believed was aided by the inherited effects of use and disuse of parts of the body (the Lamarckian factor) and by the direct action of external conditions (the Buffonian factor). Greater variations (mutations) occurred occasionally and more rapidly advanced the evolution of a species.

In 1892 August Weismann proposed his theory of the continuity of the germ plasm (that is, chromatin). According to this theory there can be no inherited effects of use and disuse of parts of the

body. The heredity-bearing chromosomes of the fertilized egg divide lengthwise, and the twin portions of each go into the nuclei of the two resultant cells; it is thus with the development of each cell of the body. In all higher animals it is only the germ cells, set apart in extreme youth, that pass on to form later generations, and hence, it is held, these cannot be influenced by the environment of the adult. According to this theory it is through competition among the minute subdivisions of the chromatin, the theoretical determinants, that variations arise. Which of these variations shall survive is determined by the selection of those adults which are best fitted to their environment. Natural selection thus becomes a pruning knife. This modification of Darwin's view has been widely accepted as a working hypothesis by many experimental scientists.

Experimentation

The modern period of experimentation as an aid to the understanding of evolution may be roughly said to begin with the opening of the present century. It was in 1900 that de Vries in Holland, Correns in Germany, and Tschermak in Austria independently rediscovered Mendel's work, sixteen years after his death. Mendel's experiments, since greatly extended by many workers, show that the sexual cells include definite unit characters which apparently do not change, at least within the time limits of the experiments. Crossing thus results mainly in a shuffling and new arrangement of definite unit characters. Such study forms the basis of the modern science of genetics.

In 1901 Hugo de Vries published the results of his observations and experiments, covering many years, on the evening primrose (*Œnothera lamarckiana*). He definitely showed that in this species new forms came into existence suddenly. When they were propagated from their own seed these mutants, as de Vries called them, bred true. Darwin believed that new species arose "chiefly through the natural selection of numerous, successive, slight, favorable variations." These are known as fluctuating variations. De Vries emphasized the thought that the variations which he observed were large. They represent saltations, that is, discontinuous variations instead of the minute continuous ones of Darwin. They are attributable to some sudden alteration in the heredity chromatin. Through mutation, characters which are not of survival value (a matter of life and death to the species) may arise and be perpetuated.

Much of the work in evolution today is concerned with the origin of variations. Darwin and his followers took these for granted. They appeared to them to be everywhere. To many in experimental work these Darwinian variations are thought of as fluctuations, oscillating about a mean. They consider them as dependent upon some action of the environment upon the individual and hence as not indicating differences in the heredity germ cells. Darwinism was concerned with the adaptation of the organism to its environment, — a question of function. The tendency of the modern experimentalist is mechanical; he looks for the origin of the parts of the machine, that is, the variations.

That variations have always been present, and that these variations have proceeded along definite orderly lines, paleontology alone abundantly proves.

Inheritance of Acquired Characters

If the variations which arise as a response to a changing environment can be inherited, we should have the simplest of explanations for the close correspondence between great geologic changes and a quickening in evolution. It would also be an added incentive to the advocates of euthenics, who rely upon the improvement of the conditions of life and training for the improvement of the inborn constitution of the race. Belief in Lamarckian transmission would stimulate every effort toward self-improvement, — bodily, intellectual, æsthetic, and moral.

It is thus clear why the problem of the inheritance of acquired characters is occupying some of the attention of the experimentalists. Held as the principal factor by Buffon, Lamarck, and many later workers, and as an accessory factor by Charles Darwin and others, it has not been definitely proved. Indeed, under Weismann's conception of the continuity of the germ plasm all inheritable variations must arise in the germ cells, and hence the possibility that impressed modifications may be inherited was denied.

Almost innumerable experiments have been brought forward claiming to prove the inheritance of acquired characters, but these have been discredited when it has been shown that they admit of other interpretations. It is, of course, recognized that mutilations are excluded; for what is done to a plant or animal cannot be inherited. It is what the organism does to itself in reaction to its environment that may possibly be inherited. It is well known that

changes in the environment induce changes in the organism. When the European wallflower is watered with salt water, it becomes succulent like seaside plants. This is a change in the body (soma) only, as it is not inherited. The question is whether long-continued action of the environment may in time impress this change upon the germ cells so that it may be inherited. This is still an open question.

The inheritance of acquired characters has been defended in the form of inherited memory (the mnemonic theory) by many writers, including Hering, Samuel Butler, Sir Francis Darwin, and William McDougall. Francis Darwin says:

> The fact that stimuli are not momentary in effect, but leave a trace of themselves in the organism is in fact the physical basis of the phenomena grouped under memory in its widest sense as indicating that action is regulated by past experience.

Plants as well as animals form habits. The rhythm of day and night movements of leaves goes on even when the plants are kept in darkness. It is a habit.

Professor William McDougall divided a stock of pure-bred white rats into two halves, training the many individuals in each half stock in successive generations to the mastery of a task and comparing these at intervals with the untrained half. Each rat in training was placed in a large tank of water. It could escape only by swimming to a gangway at either end. One of these was brightly lighted and when touched by the rat gave a disagreeable electric shock. By repetition each animal learned sooner or later to avoid this end and escape by the other. This training has continued (1928) through seventeen generations. The comparisons show that the offspring of the trained rats learn to avoid the shock much more quickly than the untrained.[1]

The mnemonic theory is an attractive one. By this means Francis Darwin accounts for the growth from seed or egg to adulthood. He says: "My view is that the rhythm of ontogeny is actually and literally a habit." The whole theory, however, needs much more observation and experimentation.

Let us sum up the origin of variations as it is viewed today. The study of the life of the past abundantly proves that species have evolved by means of variations; most of which are comparable in magnitude to fluctuations. According to the Darwinian view as

[1] William McDougall in *Forum*, 1928, pp. 244–253.

modified by Weismann these variations arose in the heredity chromatin through competition among their minute subdivisions. This is the view of many experimental zoölogists and botanists. According to the Lamarckian view variations are due to the stimulation of the organisms by the environment. In the superficial changes thus developed, time may be the unknown factor bringing about the impression of these somatic changes upon the germ cells and thus causing them to be inherited. According to the latter view the visible body changes first, and then the chromatin; according to the other view (Neo-Darwinian) the chromatin changes first, and in the ontogenetic development of plant or animal this change is impressed upon the adult.

II

THE MENTALITY OF CHIMPANZEES

The following notes were taken from a lecture that was given by Dr. Wolfgang Köhler in 1925. The lecture was illustrated by motion pictures taken at Teneriffe with chimpanzees newly brought wild from Africa. They were thus entirely untrained by man.

Bananas were hung too high in the cage to be reached from a single box. The brightest chimpanzee tried to place another box upon the first. He would push the box up from the outside only to have it fall back upon him when he tried to climb upon it. Then, climbing upon one box, he would pull and tug to bring the second box up beside him and getting upon it would jump for the bananas before the box could fall. He never learned to balance the boxes, though at times that happened by chance.

Bananas were placed outside the cage too far to be reached with one rod. There were two bamboo rods in the cage, of equal length, but one of smaller diameter. Only the brightest chimpanzee did the following. When he found that he could not reach the bananas with either stick he took the second stick and with it pushed the first until it touched the bananas and moved them. This pleased him greatly. He had made the connection between the bananas and himself. (His behavior here was exactly like that of human beings.) After a while this mere connection no longer satisfied him (as with human beings); he wished to possess the bananas. This he couldn't do, so he turned his back to them and began playing with his two rods (which he again had). After some play he happened to fit the smaller rod into the larger, making a longer rod. Immediately (for, as with human beings, this connection comes as a leap, a creation) he whirled about and began scraping and pulling the bananas one by one to the cage, where he piled them beside him. Then, apparently still more interested in his new creation than in the luscious food (again like human beings), he continued to use the tool that he had made, scraping in the stones and sticks that he could reach. The rods often came apart when thrown down while he was eating.

Each time he tried to join the rods end to end, and if he got the wrong ends (for they would fit in only one way) he would quickly turn the rod and fit in the proper end. After he had passed the early stage of creation he used the lengthened stick only as a tool to get what he wished (again like human beings).

A pole four or five times the height of the chimpanzee was placed in the cage. The bright chimpanzee took it, holding it vertical with one end on the ground, and climbed as high as he could before it toppled to the ground. Some bananas were then hung high in the cage. The same chimpanzee took the stick, placed it vertically beneath the bananas, and, hustling up the pole, grasped a banana before the pole fell. This he continued doing until he had secured all the bananas, eating each one as he got it. Other chimpanzees tried to do this, but, not making the pole vertical, they couldn't get high enough before it fell.

Some bananas were so hung that they could be reached by climbing up a door and swinging it outward. Later this door was fastened against the wall by a rope passing across it. The bright chimpanzee climbed up the cage, pulled the rope off one staple, then, jumping upon the door and shoving against the side of the cage, swung out and got a banana. Next a stone almost as large as the chimpanzee was placed against the base of the door and the rope again fastened to staples. The chimpanzee, climbing up, loosened the rope from a staple and, springing upon the door, tried to swing it out as usual, but failed. He saw the stone and, jumping down, pulled and tugged at it to drag it from the door. He moved it for a short distance, then climbing again to the door top found that it didn't swing far enough. After he had dragged the stone for the third time, he could swing the door straight out and thus get the coveted banana.

After showing these acts on the films, Dr. Köhler told the following of his chimpanzees:

A box was placed in a corner of the cage where were put the newly arrived chimpanzees. A banana hung from the cage ceiling but could not be reached by simply jumping. A bright chimpanzee went to the box and sat upon it, apparently to think out this food problem. The box moved slightly, whereupon he shoved the box directly beneath the banana and, climbing up, got the fruit. A stupid chimpanzee, after seeing the other do this a number of times, saw an apparent connection between the box and the banana, so he climbed upon the box, then leaped from it to the center of the cage where hung the banana, and jumped for it. He couldn't get it. How-

ever, after having seen the box moved several times beneath the fruit by the other chimpanzee, he perceived the connection between the movement of the box and the banana. So he shoved the box, but not toward the banana, and then, climbing upon the box, leaped from it and ran toward the banana and jumped. The complicated ideas of box, movement, and direction (coördinated at once by the brighter chimpanzees) were too much for the dull ones to encompass, just as the pole and its verticality comprised too great a problem for some.

When lower animals, dogs, cats, hens, were experimented with, they were found to increase gradually in intelligence, but the chimpanzees were like human beings in that illuminating ideas came suddenly.

III

KITCHEN MIDDENS AS ETHNOLOGICAL RECORDS

As our present city waste dumps will give to the future paleontologist a conception of some phases of our material civilization, so the waste allowed to accumulate around the dwellings of early man gives us at least some indication of his stage of development. Very early man, influenced by a trait which inheritance has made comprehensible to us, threw the waste of food and clothing immediately outside his dwelling, there to accumulate. To such masses of débris the name *kitchen midden* (literally, kitchen refuse heap) has been applied. Since in many regions the available food of that time consisted largely of shellfish, the name *shell mounds* is also applied to these heaps of refuse.

Kitchen middens vary greatly in size, from the length of a foot to that of a mile or more and from the thickness of a fraction of an inch to that of one hundred feet, — from the few shells, bones, and charcoal of a solitary hunter about his temporary camp to the accumulations of a large village inhabiting the same locality through many centuries. Usually they have a diameter of from fifty to a hundred feet and a maximum thickness of from two to five feet. In the permanent villages the dwelling came in time to occupy a depression in the accumulated mass. Besides being a repository for the waste of food, clothing, and implements they were likewise, in many parts of the world, used as burial places, just as many lowly tribes today bury their dead beneath their dwellings, to keep them from disturbance and to have the protection of their spirits against enemies.

The distribution of kitchen middens is world-wide; they are found on all continents. They usually occur on the margins of bays or inland along streams and lakes. In America they frequently occupy the same sites as the later white settlements, and for the same reason, — accessibility to water, food, and wood. The character of the middens naturally varies with the character of the food. Along the ocean margins the waste was marine shells and the bones of fish

and mammals; inland it was fresh-water shells and the remains of land animals, though the presence here of some marine forms indicates a system of traffic such as was practiced by the Indians at the time of the arrival of the whites.

The shell mounds of the coasts of Maine and northeastern Massachusetts contain the remains of the clam, oyster, quahog, hen clam, scallop, deer, beaver, wild turkey, great auk, and many kinds of fish; with these occur fire pits, charcoal, flint implements, and a little pottery. There are many remains of animals now absent or very rare in these regions; among these are the oyster, quahog, wild turkey, and great auk. The presence, in a midden at Ipswich, Massachusetts, of human bones broken into short pieces as for the cooking pot gives possible indication of cannibalism. This practice has been shown to have occurred at other places along the Atlantic coast, as in Florida.

The remains of shell mounds indicate that they were accumulated by peoples but slightly if at all acquainted with agriculture, whose subsistence depended mostly upon fishing and hunting. Some mounds in the San Francisco Bay region must have been occupied for a duration of at least four or five thousand years. This estimate is based largely upon the probable number of shellfish, birds, and mammals eaten by one individual and the approximate number of individuals in the village, reckoning each depressed area as the dwelling place of one family. Some of the mounds were occupied after the advent of the whites. The same is true on the Atlantic coast. In the Ipswich mound referred to above, it was only near the top of the mound that any objects of European make were found. Similarly, on this coast the presence of rare or entirely extinct species gives evidence of the lapse of many centuries since early man began here his primitive housekeeping. In the Americas the Indian is, at least in many cases, known to be the direct descendant of the kitchen midden inhabitants.

Kitchen middens vary in abundance with the suitability of a region for habitation. In the San Francisco Bay region four hundred and twenty-five good-sized mounds have been counted. They are also very numerous along the Atlantic coast from Newfoundland to the West Indies and around the Gulf. They are very abundant in France, Denmark, Scotland, Italy, and Japan. In northern Italy they have received the name of terramara (bitter earth). They contain few or no shells but are phosphate deposits. They represent

the accumulations beneath dwellings built on piles, and their slow accretion took place during the time when this region, especially that lying between the River Po and the Apennines, was gradually changing from a condition of shallow lakes, or marshes with frequent inundations, to that of dry ground. These dwellings apparently reached their greatest development about the fifteenth century B. C. The terramara deposits are apparently intermediate between the kitchen middens proper (shell mounds) of northern Europe and elsewhere and the lake dwellings of Switzerland; the different kind of accumulated waste indicates the kind of dwelling used, the food eaten, and the implements used.

IV

SUCCESSION OF PLEISTOCENE CULTURES

CULTURES OF THE NEANDERTHAL RACES

Among the Neanderthal races various cultural types have been described, from the primitive Cromerian of the early Pleistocene, through the pre-Chellean, Chellean, Acheulian, and Mousterian.

Cromerian. The earliest known of these races, the Heidelberg, were primitive men of giant size. They may have manufactured such huge and varied flint implements as are found at Cromer in Norfolk on the east coast of England, which are thought by some scientists to be of the same geological age as the Heidelberg jaw. Pithecanthropus seems best interpreted as a representative of a very primitive race surviving to Pleistocene times, a case of arrested development, due to the life of ease in the subtropical forests of southern Asia. Pithecanthropus had a brain capacity of 940 cubic centimeters, which is not far inferior to that of the native Indian Veddas (1000 cubic centimeters).

Chellean. Succeeding the Cromerian culture period are the pre-Chellean (not well known) and the Chellean. The type locality of the latter culture is Chelles, France, where, in sand quarries in the bottom of the Marne valley, many implements are found. Coarsely flaked implements of this stage of development have been found in southern and western Europe and across the Mediterranean in the northern Sahara. Associated with Chellean flints in France are remains of the saber-toothed tiger, the straight-tusked elephant (*Elephas antiquus*), the broad-nosed rhinoceros (*Rhinoceros mercki*), and, as further indication of the warm climate of this period, the fig and the sweet bay.

Acheulian. To the many centuries of the Chellean period there gradually succeeded a colder climate. The animal and plant forms of the warm forests of Europe either died off or migrated southward, and their place came to be taken by the life of grassy, treeless steppes. By this time man's implements had developed into what is known as the Acheulian type, from its typical occurrence at

St. Acheul, a suburb of Amiens, France. These implements are more carefully and sharply pointed than the Chellean and more finely chipped.

Mousterian. The colder climate of the Acheulian epoch finally culminated, in Europe, in the glacial conditions of the Mousterian epoch, when man lived largely in caves and rock shelters. Many of the grassy steppes had by this time become impoverished mossy plains or tundras. The number of food plants grew fewer and fewer, and man lived largely by the hunt, — upon the wild horses and wild cattle of the steppes, the mammoth (*Elephas primigenius*), and the reindeer, as is shown by the bones around their hearths. These have since been buried by the mud and sand washed from the higher lands or by the drip from the limestone caves. Spears and darts were the chief implements of the chase. Doubtless a large share of the daily life was carried on before the entrances to the caves; yet the majority of these caves were larger and better ventilated than the smoky cabins of many white people a hundred years ago, or the tepees of the plains Indians of North America.

The Mousterian is the culture period of the Neanderthal race, the best known of all the Neanderthaloid stock. It derives its name from Le Moustier cavern in southern France. Here implements were found associated with a skeleton which showed that the body had been laid in a position of ceremonial burial with the head resting on a flint plate of careful workmanship. Other culture conditions of at least some of this race are shown by the skeletons found in the pit of Krapina in Croatia, a pit which is now filled with glacial sands, but which was once in the bed of a brook. The remains were of about ten individuals of different ages, and the shattered and burned condition of the bones is held to indicate that they are the relics of a cannibal feast.

In height the men of this race were about five feet three inches. The limb bones were massive, with the thighs and shin bones curved, suggesting a somewhat stooping gait, with the knee joint not straightening at each step.

The Mousterian culture continued from the beginning of the third glacial advance into the fourth. The two advances are often grouped together as a single advance, because the interglacial epoch separating them was brief and apparently affected only a part of Europe.

Characteristic implements of this type were found in 1923 in northern China, in the vicinity of Ordos (in the great bend of the

Hwang Ho). They occurred at the base of the loess which is here fifty feet thick and which corresponds to the latest stages of the Pleistocene of Europe and North America. Associated with the implements were the remains of many animals of that period.

CULTURES OF *HOMO SAPIENS*

Three culture periods are well known among the Pleistocene peoples of this species of man.

Aurignacian culture. The Grimaldi, a negroid race, found their way into southern Europe in the early part of the upper Pleistocene. They apparently never became established here as a race of any great influence.

The first of the advanced races to dominate Europe was the Cro-Magnon. Their culture takes its name from Aurignac in southern France, where implements were found in abundance. The Cro-Magnons are sometimes called the Paleolithic Greeks. They are the earliest known sculptors and painters. Since they probably had the bow and arrow and were of great mental superiority, their coming was in the nature of a catastrophe as far as the Neanderthal race was concerned. In no less than eighteen places the Aurignacian industry succeeds immediately upon the Mousterian. There appears to be no evidence in burials or otherwise that the Cro-Magnons mixed with the Neanderthals. Hence it seems probable that the invading race found it necessary to their very existence to kill all (men, women, and children) of the race so inferior to them in every respect. That the struggle continued for some time is evidenced by the occurrence in several places of Cro-Magnon implements beneath late Mousterian ones. We may compare this contact of Cro-Magnons and Neanderthals with the invasion of America by the Europeans, though in America the difference between races was practically only one of culture.

The Cro-Magnons appeared in Europe at the beginning of the retreat of the last glacial advance. Many of them lived in caves as had the Neanderthals, but many lived also in skin huts or wooden shelters built of logs, as is shown by engravings on the walls of caves. Their burial customs were rather similar to those of the Neanderthals. Both buried their dead with ceremony. The body was interred near the shelters or at the entrance to the caves and was accompanied with implements of industry and warfare and

with food. The Neanderthals buried with the body fully extended; the Cro-Magnons, in like manner or with the limbs flexed. In the two known burials of the Grimaldi the limbs were flexed and very tightly bound to the body, probably with skin garments or thongs.

The Aurignacian culture has been discovered all around the Mediterranean, — in Spain, France, Germany, Austria, Poland, southern Russia, Syria, and Algiers. It was also found in 1923 in the vicinity of Ordos, in northern China, under fifty feet of upper Pleistocene loess.

According to Boule the Cro-Magnons were not killed off by subsequent invasions but gradually merged with the various invaders. He holds that in certain places, as in the Dordogne in France, they are surviving today in greater purity than elsewhere in Europe and that they are best preserved in the Guanche element of the Canary Islands.

Solutrean. The succeeding stage of culture is typically represented at Solutré in eastern France, where are the remains of a large camp of this period. The tundras had given place more fully to steppes or prairies where roamed herds of horses, which formed much of the food of these hunters. Fragments of about 100,000 horses mingled with bones of other animals of the chase formed a sort of rampart around the Solutré camp. There is no evidence that man raised the horses for food or other uses.

This was the acme of the Paleolithic working of flint, characterized by the finely chipped lance heads, mostly of laurel-leaf shape and with a notch for the attachment of a haft. Sketches were made on deer horns, mammoth ivory, bones and teeth of animals, and stones, and bas-reliefs were carved from them.

Magdalenian. The Paleolithic age and the Pleistocene period in Europe closed with the Magdalenian culture, so named from the cave of La Madeleine in Dordogne in France. The region had become warmer and well forested. That the climate was still colder than at present is indicated by the figure of the northern glutton carved on a bit of bone from a Dordogne cave and by the remains of some northern varieties of moss. Deer antlers are carved with engravings of various animals. The walls of the caves of this period are adorned with sketches of the mammoth, horse, bison, swan, wild goose, trout, pike, and salmon. Wall sketches have already been found in some thirty caves of southern France and northern Spain. The fact that nearly all the animals pictured were useful to

these hunter and fisher folk suggests that the sketches were used as a sort of magic. It is a common primitive idea that the possession of a picture gives power over the object pictured, and thus would make easier the capture of food animals.

An interesting type also associated with the Magdalenian culture is the Chancelade man. This man is similar to the present-day Eskimo of Labrador and Greenland, not only in physical appearance but also in culture; both are also most artistic in sculpturing figures in the round. It is suggested that these Chancelade hunters followed the cold climate northward as the glaciers melted back before the increasing warmth.

V

ORIGIN OF HISTORICAL RACES

The origin of various historical races is given by Boule in "Fossil Men" somewhat as follows: The world of today is populated, aside from the negroes, by round-headed (brachycephalic) individuals, such as the Alpine race in Europe and the Mongolians in Asia, and two divisions of long-headed (dolichocephalic) races. Of these two the one, dark, of small stature, is known as the Mediterranean race, the other fair, of large stature, is the Nordic. The Mediterranean today dominates the region around the Mediterranean Sea; the Nordics, northwestern Europe; while the Alpine race wedges westward through Europe between these two, from a broadly extended base in eastern Russia.

During the Neolithic period long-headed individuals, some of them a persistence of the Cro-Magnon type, were by far the most numerous; but round-headed, Alpine types increase in number from the early to the late Neolithic. There were also present intermediate types.

At the end of the Neolithic period great invasions of peoples belonging to the Alpine stock brought with them the knowledge of smelting and the manufacture of bronze implements. In Great Britain the burial mounds, or barrows, became round with the incoming of these Alpines, replacing the long barrows of the long-headed Neolithic people. In Scandinavia and neighboring areas the Nordic peoples adopted the bronze-making arts introduced by the Alpines, but excluded the people.

The Iron Age in Europe corresponds with the maximum expansion of the Nordic race. Peoples of this race invaded Great Britain and penetrated south into Spain and northern Italy and along the Danube into Asia Minor. These pioneering Nordics include the Gauls, Belgians, Teutons, Franks, Normans, and Goths. In some regions, however, such as Russia, they were driven back by members of the Alpine race, the Slavs, and the Mongols. During this period the Mediterranean peoples maintained their territories in spite of some pressure from the Nordic advance guards.

The Alpine race included such ancient peoples as the Hittites, Akkadians, and possibly the Sumerians. Apparently this race can be only of Asiatic origin. Boule thinks that it belongs to the great brachycephalic stock of central Asia, comprising both white and yellow (Mongol) peoples, — that after the end of the Glacial Period, as the fauna of the steppes moved westward into Europe, these peoples followed, at first slowly, during the Neolithic period, and in great numbers in the Bronze Age, and that as they moved westward they lost some of their mongoloid characters.

The ancient Mediterranean stock included the old peoples of north Africa, such as the Egyptians and Libyans, and also the Phœnicians, Pelasgians, Etruscans, and Iberians.

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